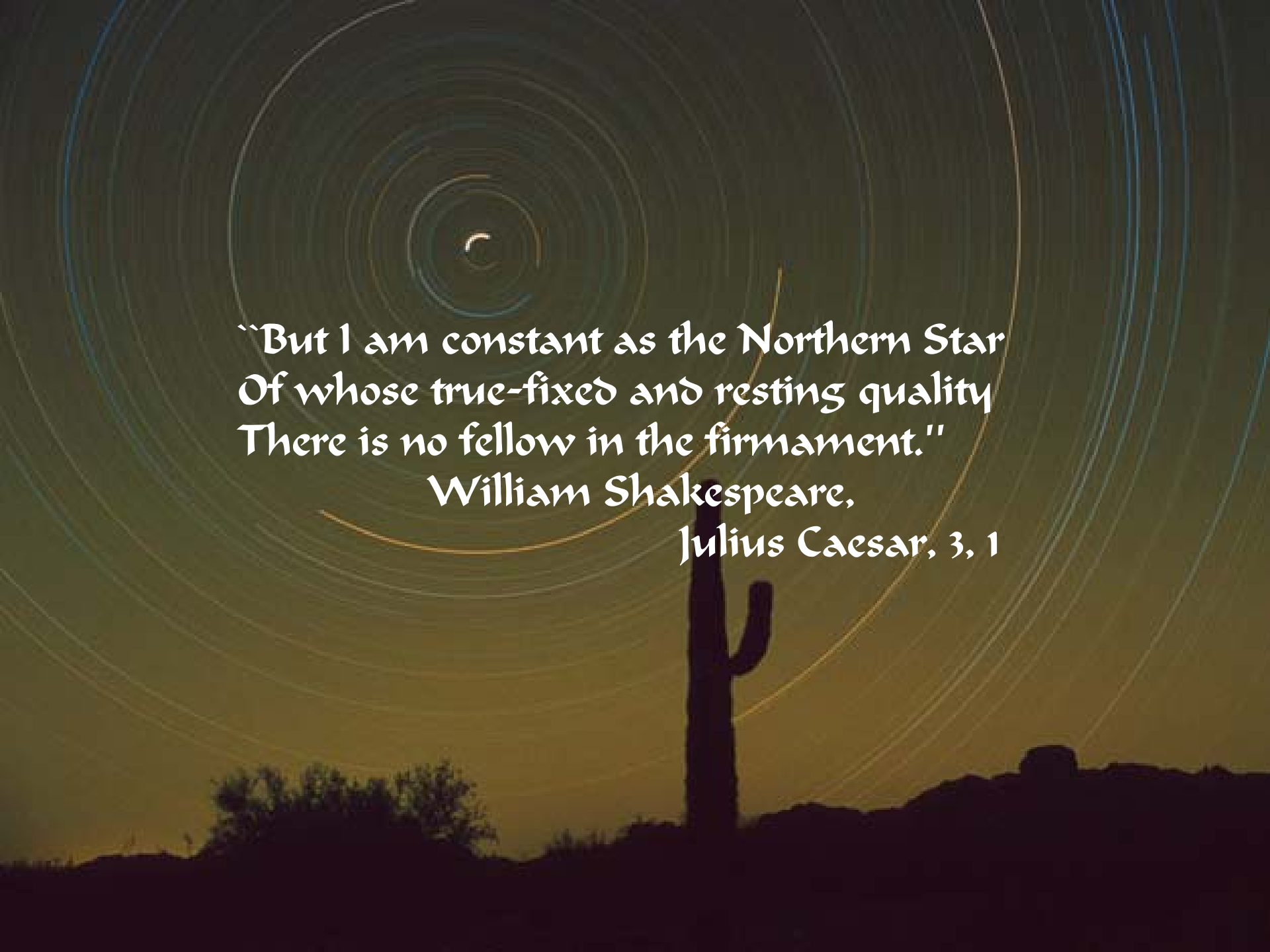

``But I am constant as the Northern Star
Of whose true-fixed and resting quality
There is no fellow in the firmament.''
William Shakespeare,
Julius Caesar, 3, 1

Astronomy C - Variable Stars - 2009

A. Pulsating Variables:
    1) Long Period Variables
        a) Mira type
        b) Semiregular
    2) Cepheids
    3) RR Lyrae
B. Cataclysmic (Eruptive) Variables:
    1) Recurrent Novae
    2) T Tauri
    3) Symbiotic
    4) U Geminorum
    5) X-Ray Binaries
    6) Supernovae
        a) Type II
        b) Type Ia
C. Eclipsing Binaries

Astronomy C - Variable Stars - 2009

A. Pulsating Variables:
- 1) Long Period Variables
  - a) Mira type Mira, RV Virginis
  - b) Semiregular Betelgeuse
- 2) Cepheids RS Puppis
- 3) RR Lyrae

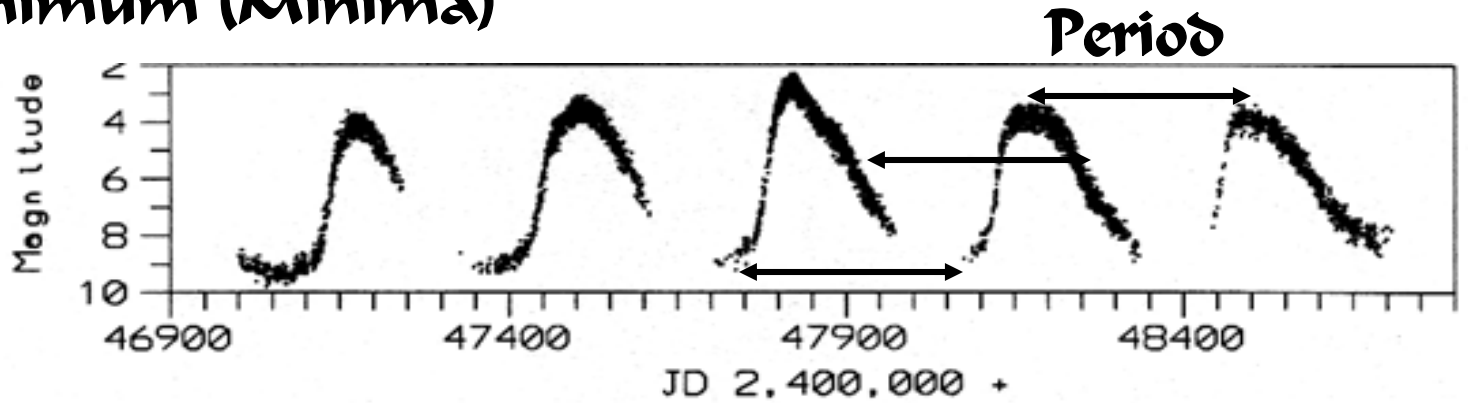
B. Cataclysmic (Eruptive) Variables:
- 1) Recurrent Novae RS Ophiuchi
- 2) T Tauri T Tauri
- 3) Symbiotic Z Andromedae
- 4) U Geminorum RX Andromedae
- 5) X-Ray Binaries Circinus X-1
- 6) Supernovae
  - a) Type II G292.0+1.8,
  - b) Type Ia SN 1006

C. Eclipsing Binaries Epsilon Aurigae

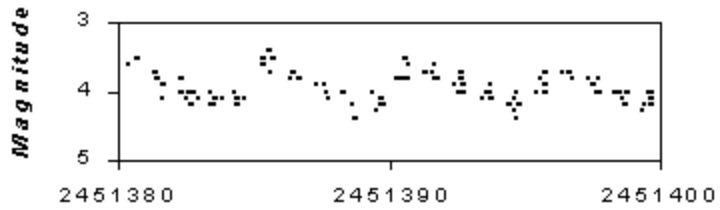
Light Curves - Variation over Time

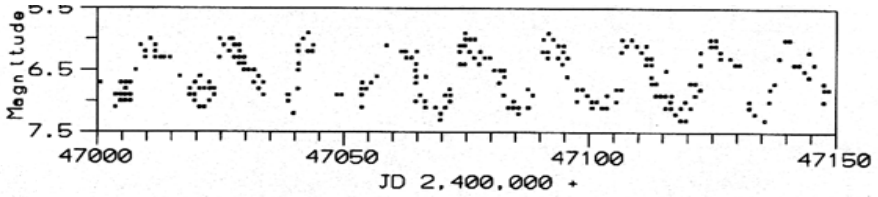
Maximum (Maxima)

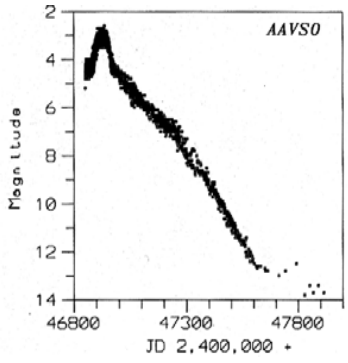
Minimum (Minima)

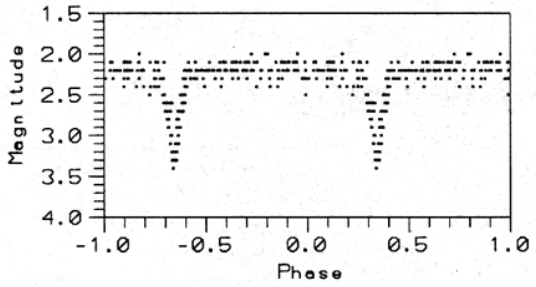


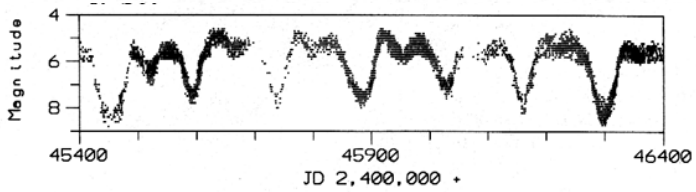
Apparent Magnitude vs Julian Day









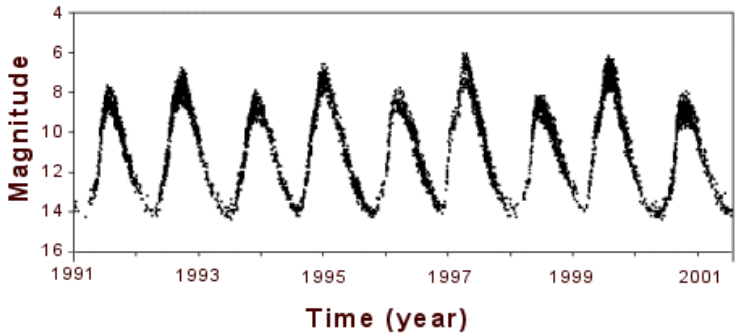


A. Pulsating Variable Stars;

1) Long Period Variables (LPVs)

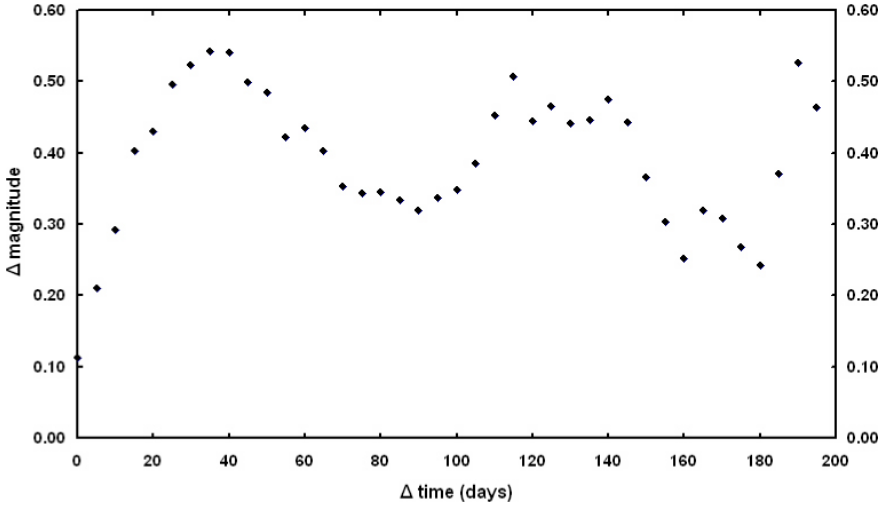
a) Miras 80 - 1000 days, 2.5 - 5.0 mag

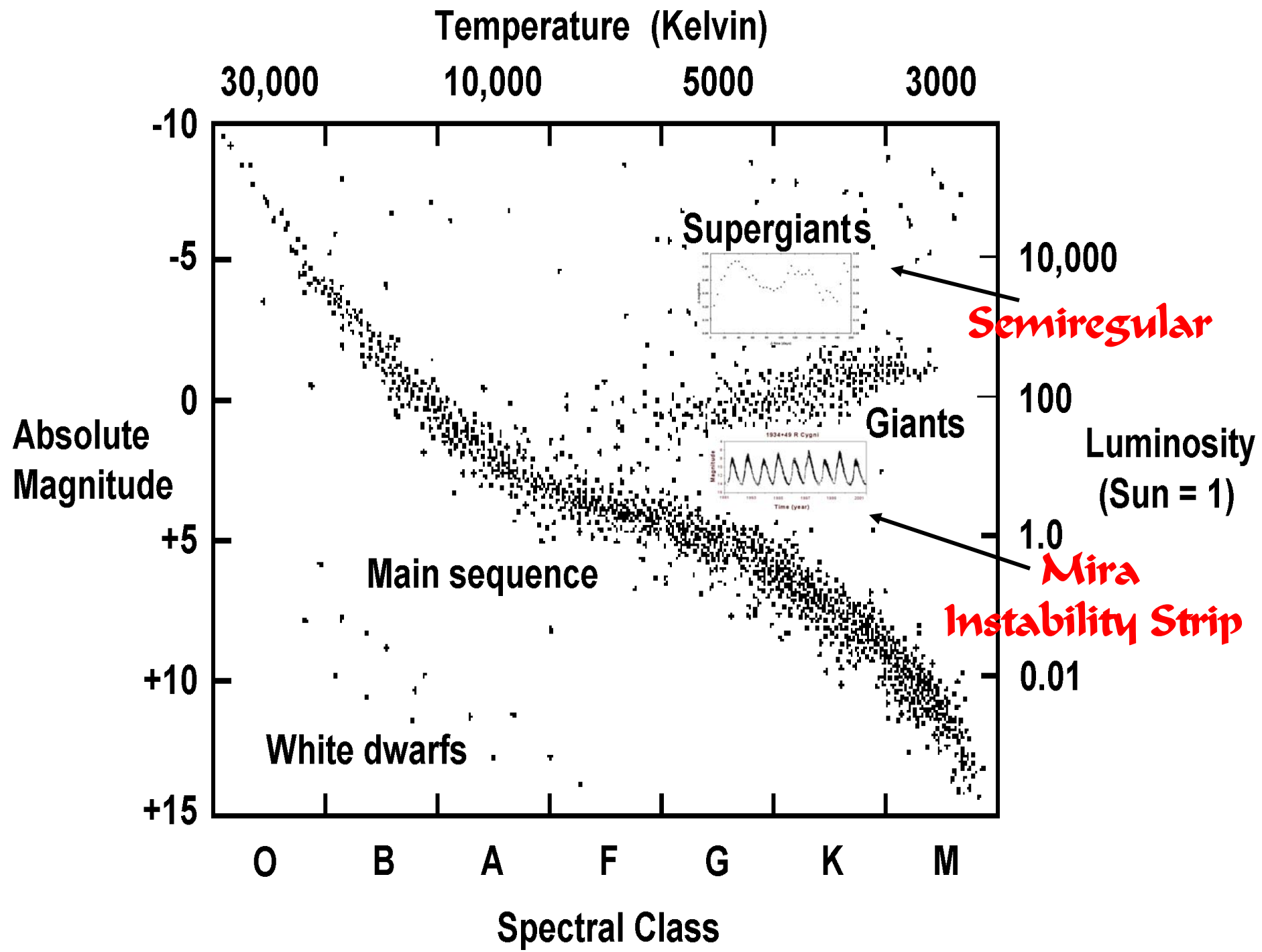
Mira
RV Virginis



b) Semiregular Variables 30 - 1000 days, 1.0 - 2.0 mag

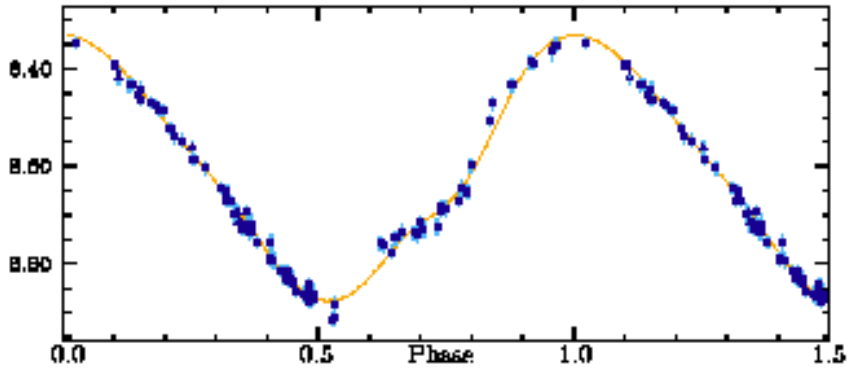
Betelgeuse

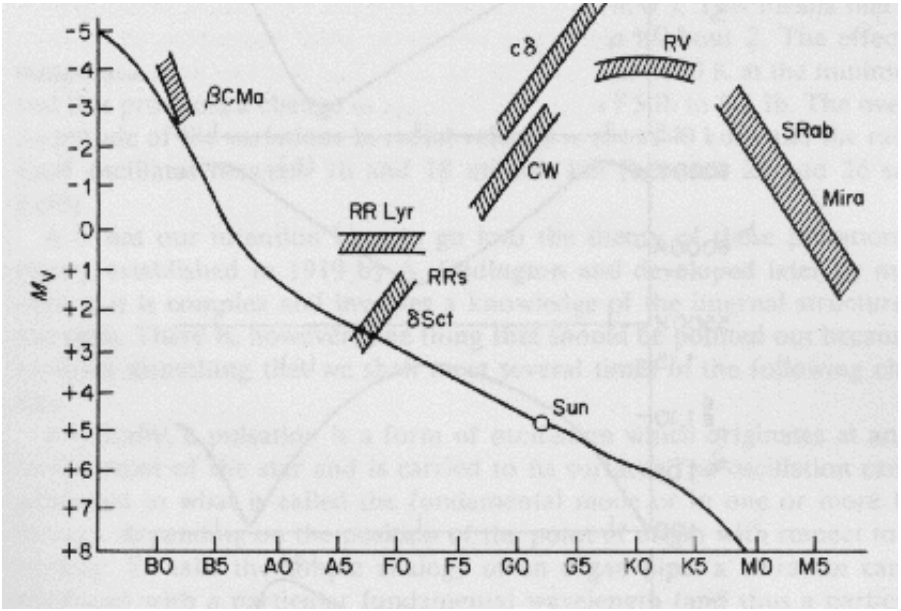



Temperature (Kelvin)
30,000
10,000
5000
3000
-10
-5
0
+5
+10
+15
Absolute Magnitude
Supergiants
Giants
Main sequence
White dwarfs
10,000
100
1.0
0.01
Luminosity (Sun = 1)
Semiregular
Mira
Instability Strip
O
B
A
F
G
K
M
Spectral Class

2) Cepheid Variable Stars

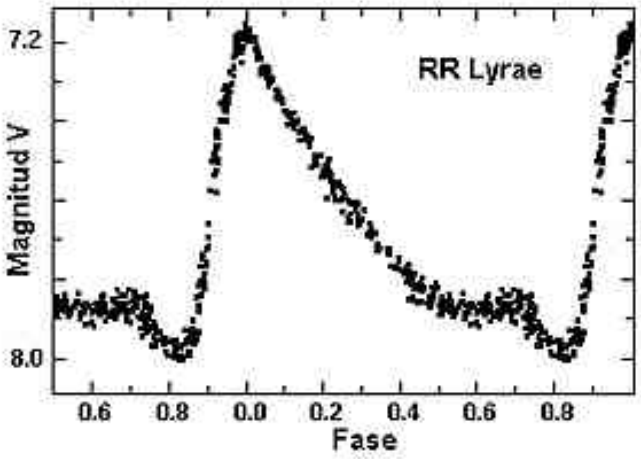
RS Puppis [Periods of .8 - 35 days, .3 - 1.2 mag]

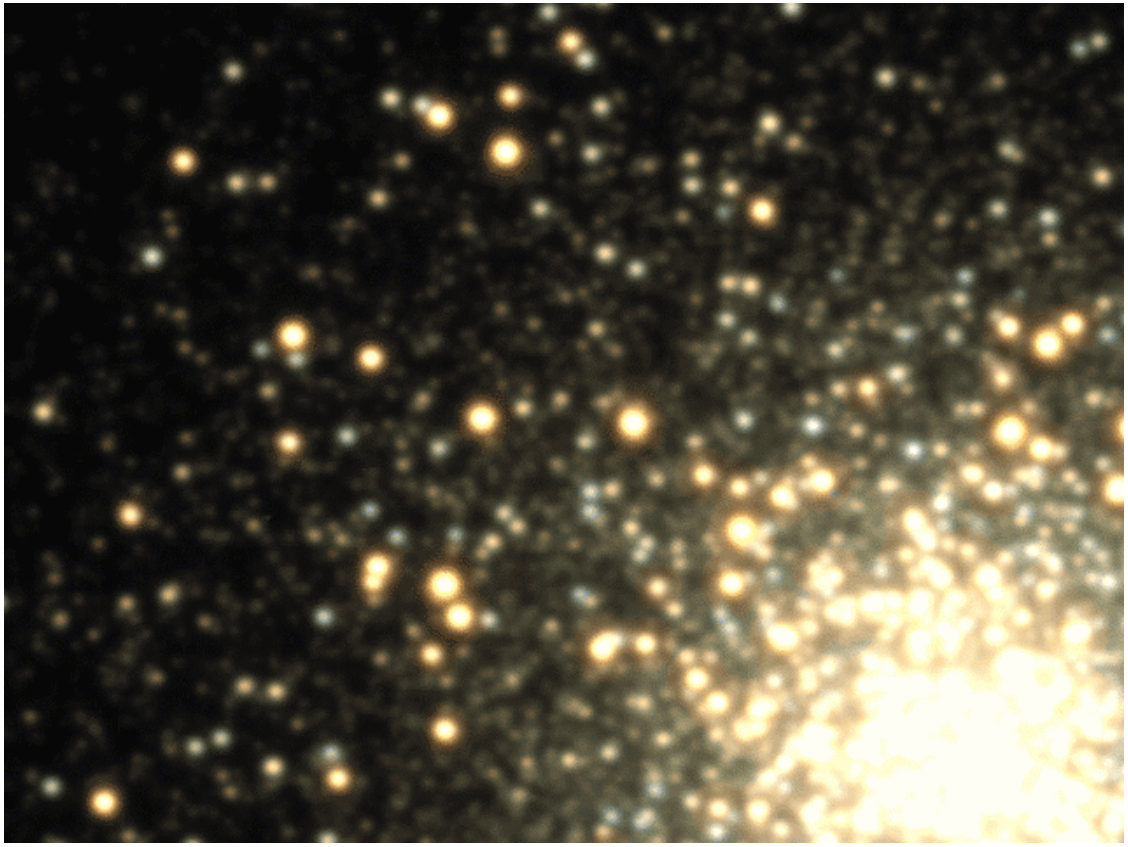




3) RR Lyrae Variable Stars

[Periods of .2 - 1 day, .3 - 2.0 mag]

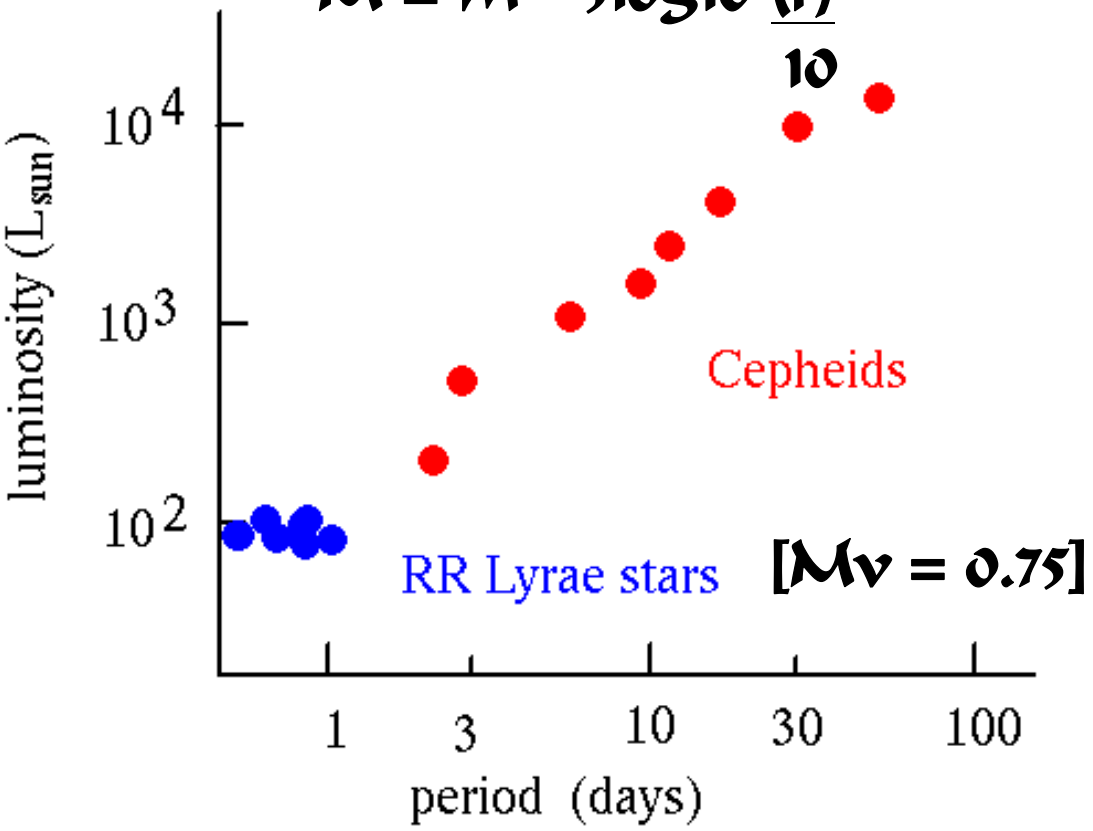


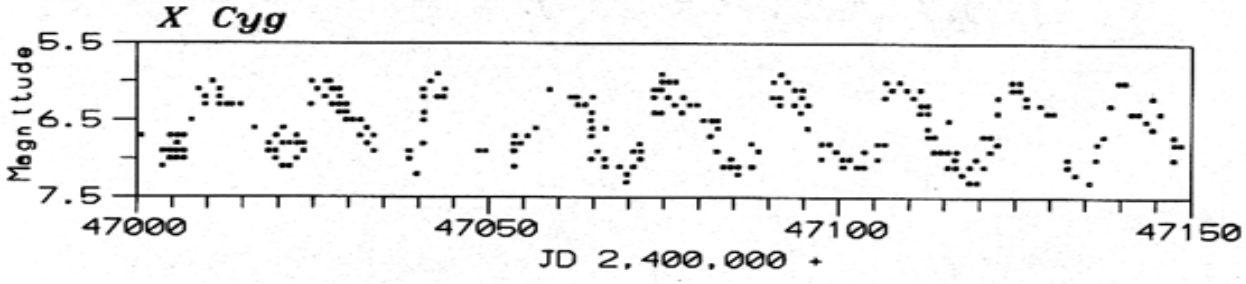


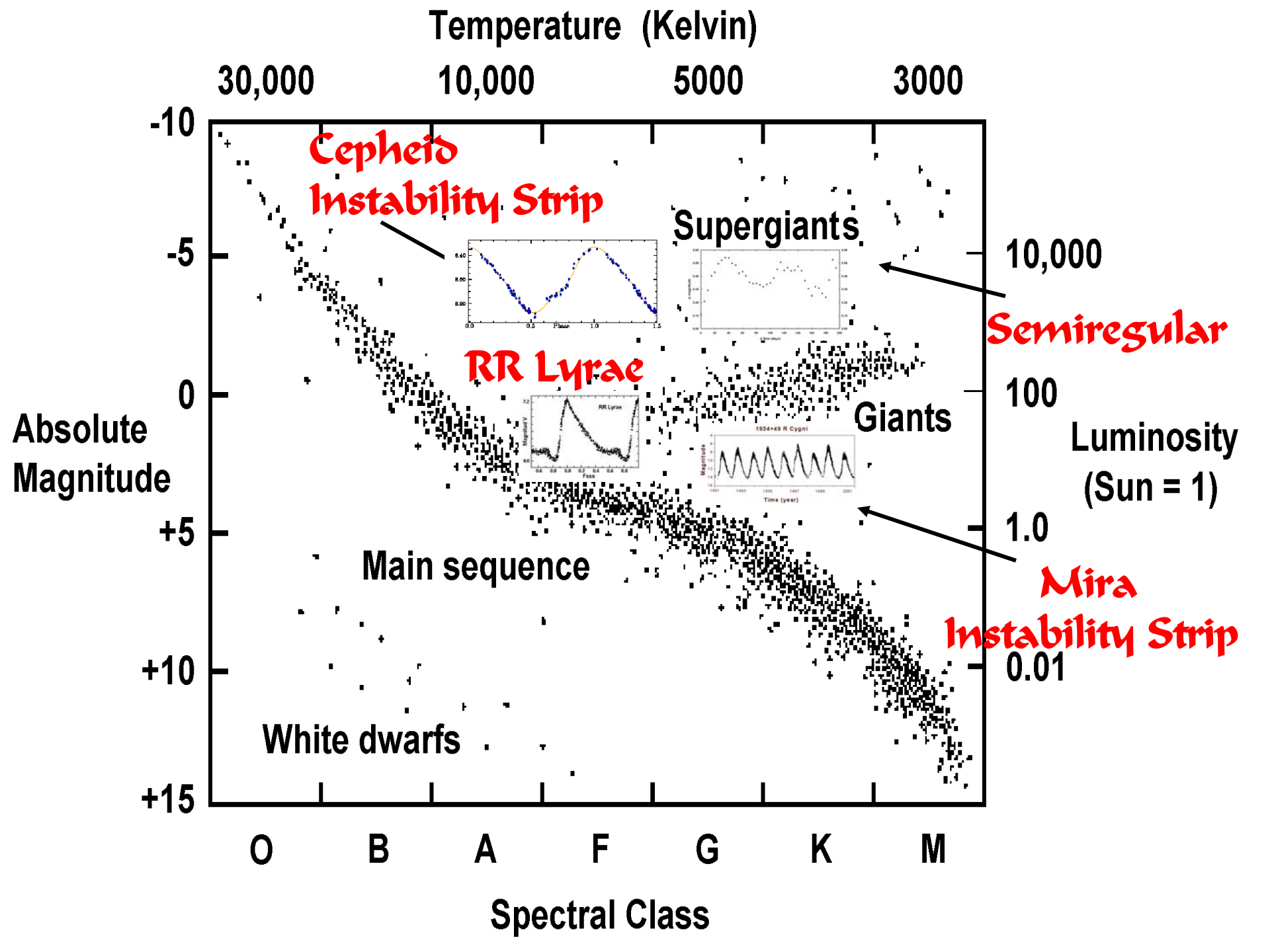
Cepheid and RR Lyrae Variable Stars

Period-Luminosity Relationship and The Distance Modulus:

$$M = m - 5\log_{10}\left(\frac{r}{10}\right)$$



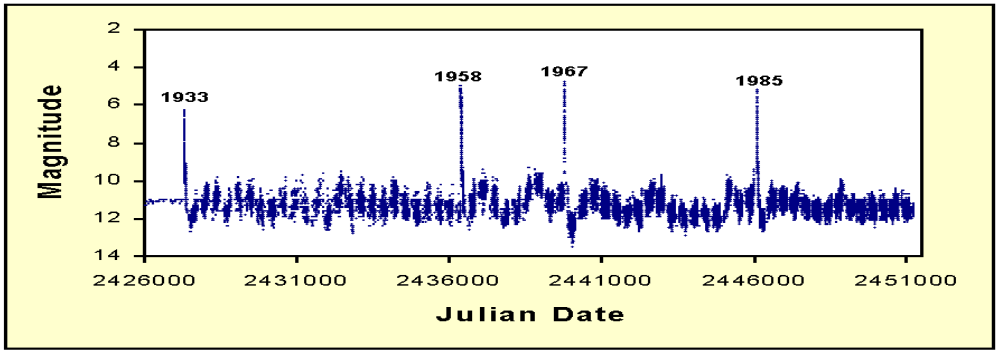


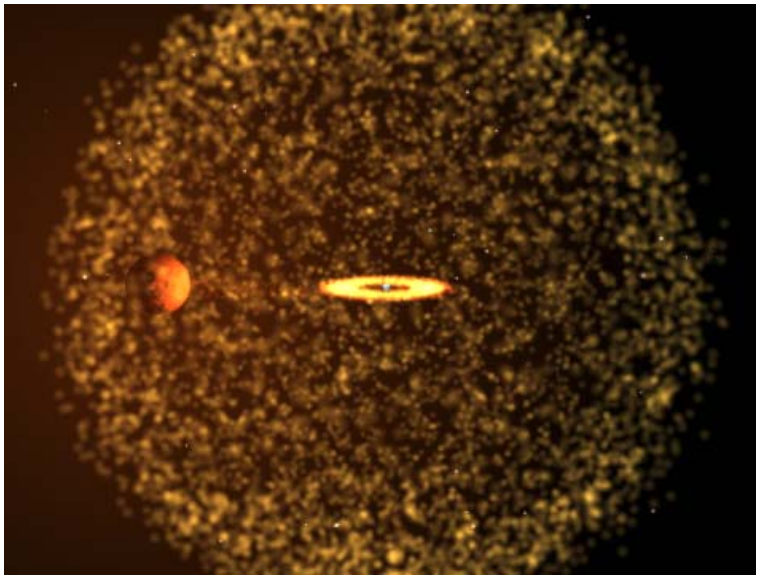

Temperature (Kelvin)
30,000
10,000
5000
3000
-10
-5
0
+5
+10
+15
Absolute Magnitude
Cepheid Instability Strip
Supergiants
RR Lyrae
Giants
Main sequence
White dwarfs
10,000
100
1.0
0.01
Luminosity (Sun = 1)
Semiregular
Mira Instability Strip
O
B
A
F
G
K
M
Spectral Class

B. Cataclysmic (Eruptive) Variables

1) Recurrent Novae [1-200+ days, 7 - 16 mag]

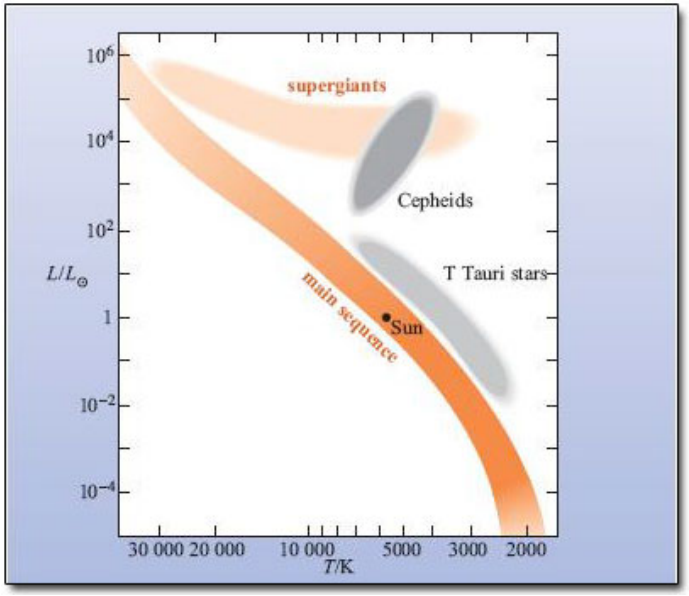
RS Ophiuchi

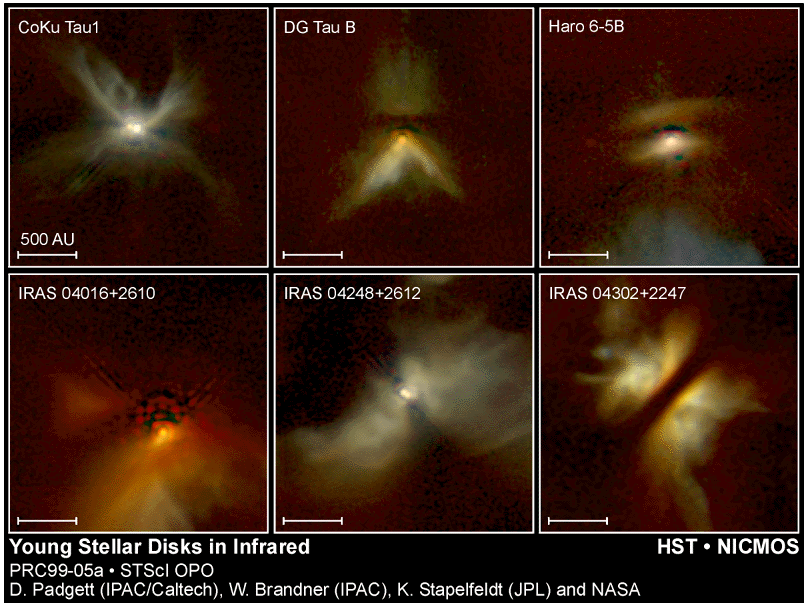


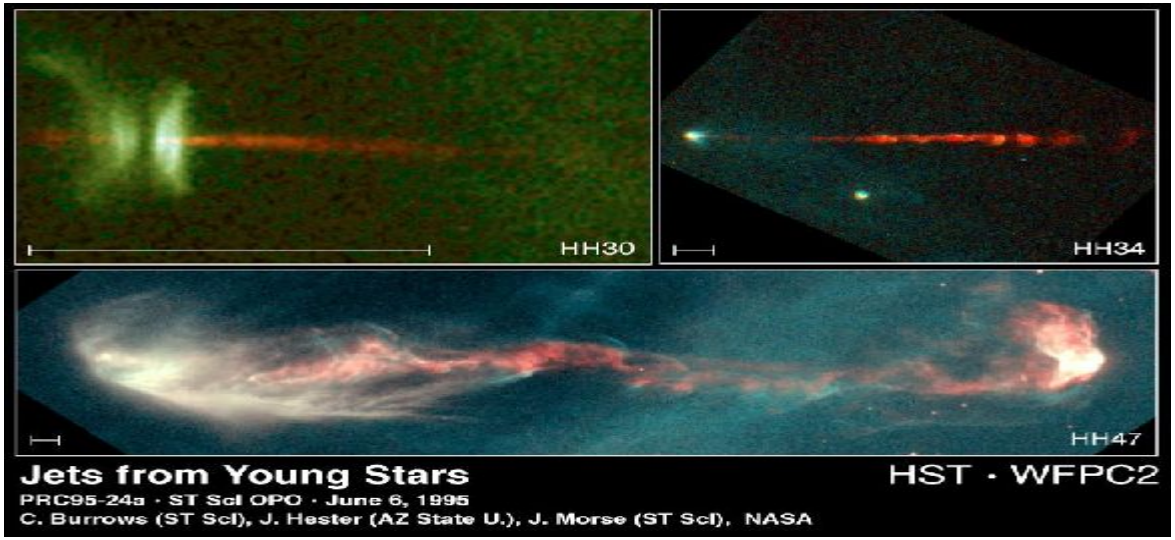


2) T Tauri - pre main sequence proto-star

T Tauri [irregular and unpredictable]



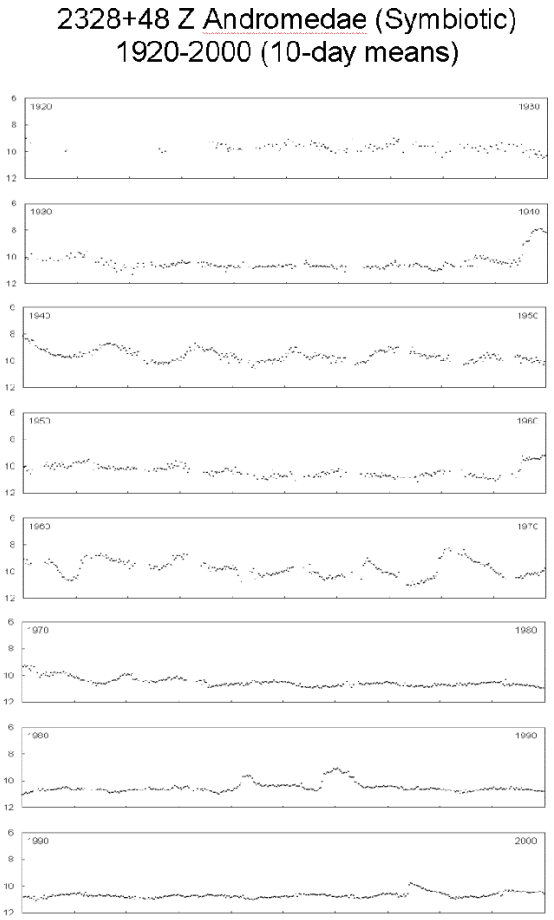


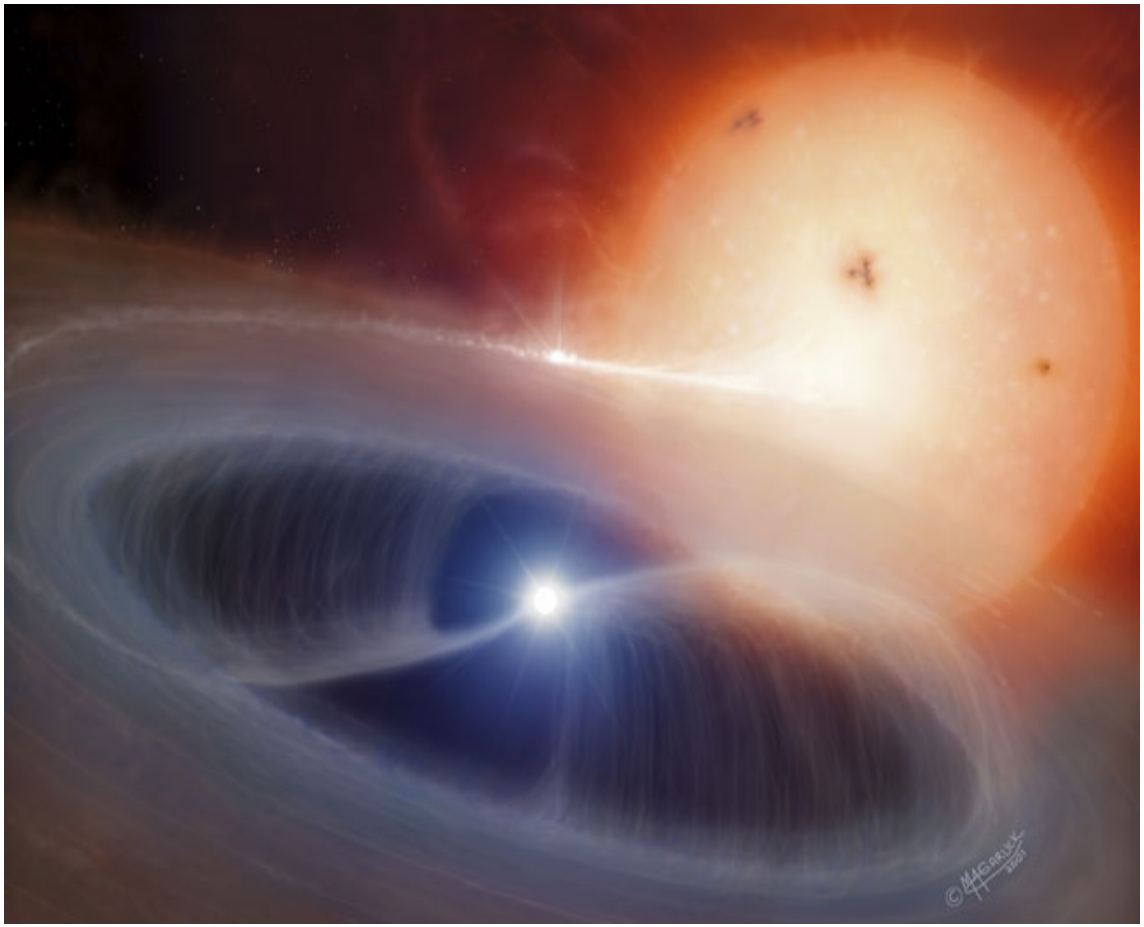


3) Symbiotic

Close Binary System - red giant and massive blue star both embedded in nebulosity

Z Andromedae [Semi-periodic, up to 3 mag]

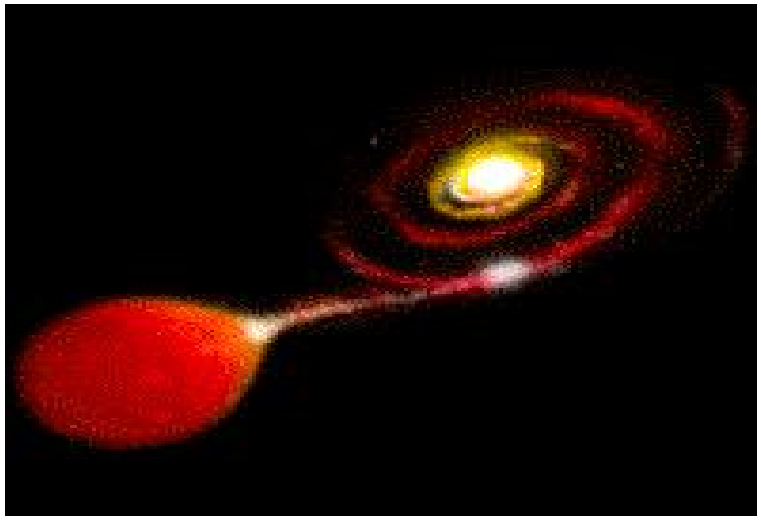


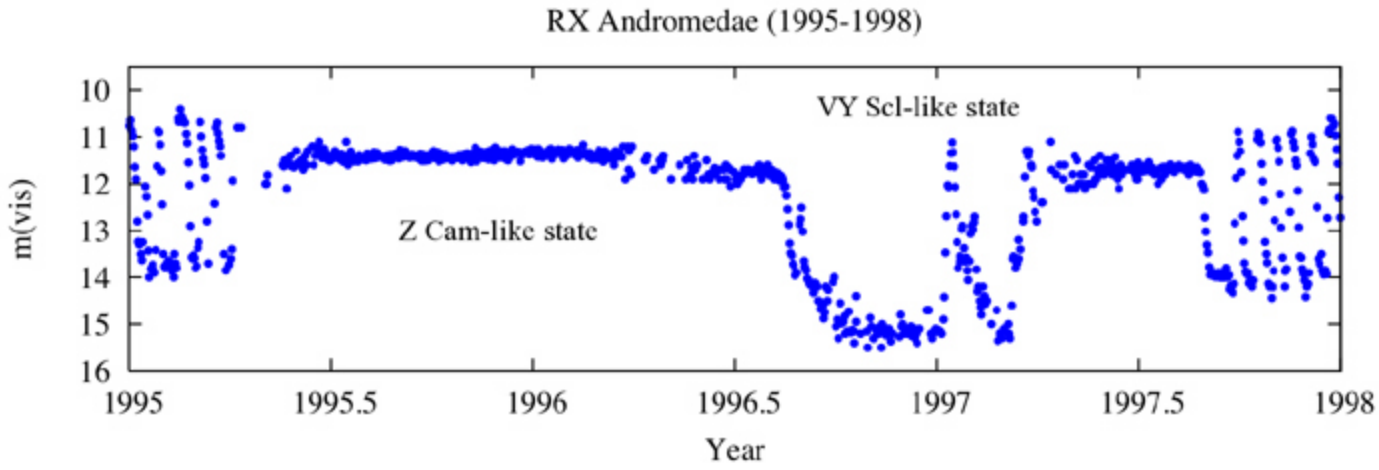


4) U Geminorum [30-500 days, 2-6 mag]

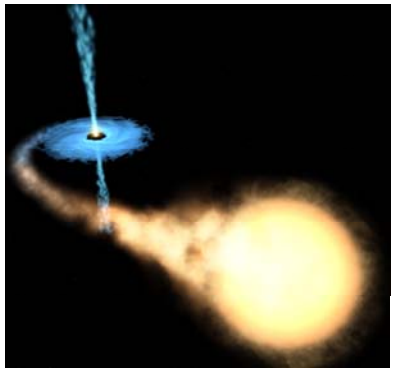
after intervals of quiesence suddenly brighten for 5 - 20 days - in a dwarf novae type system

RX Andromedae



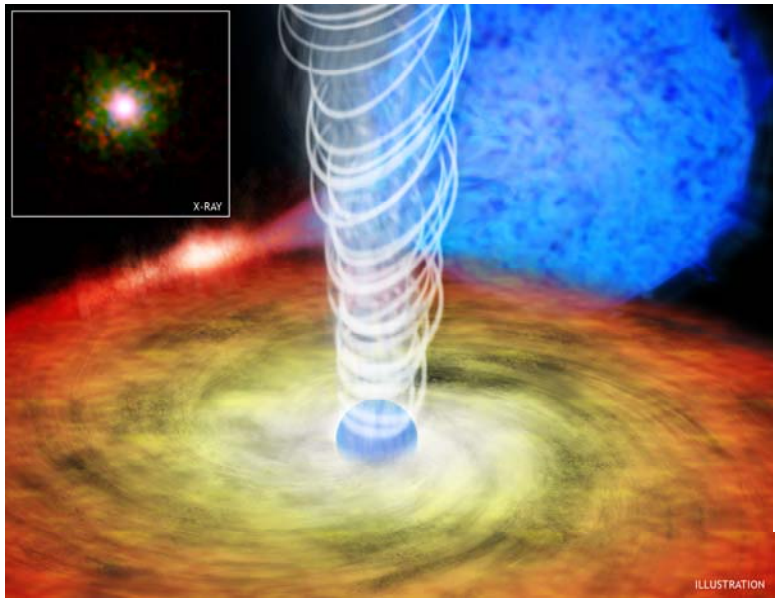


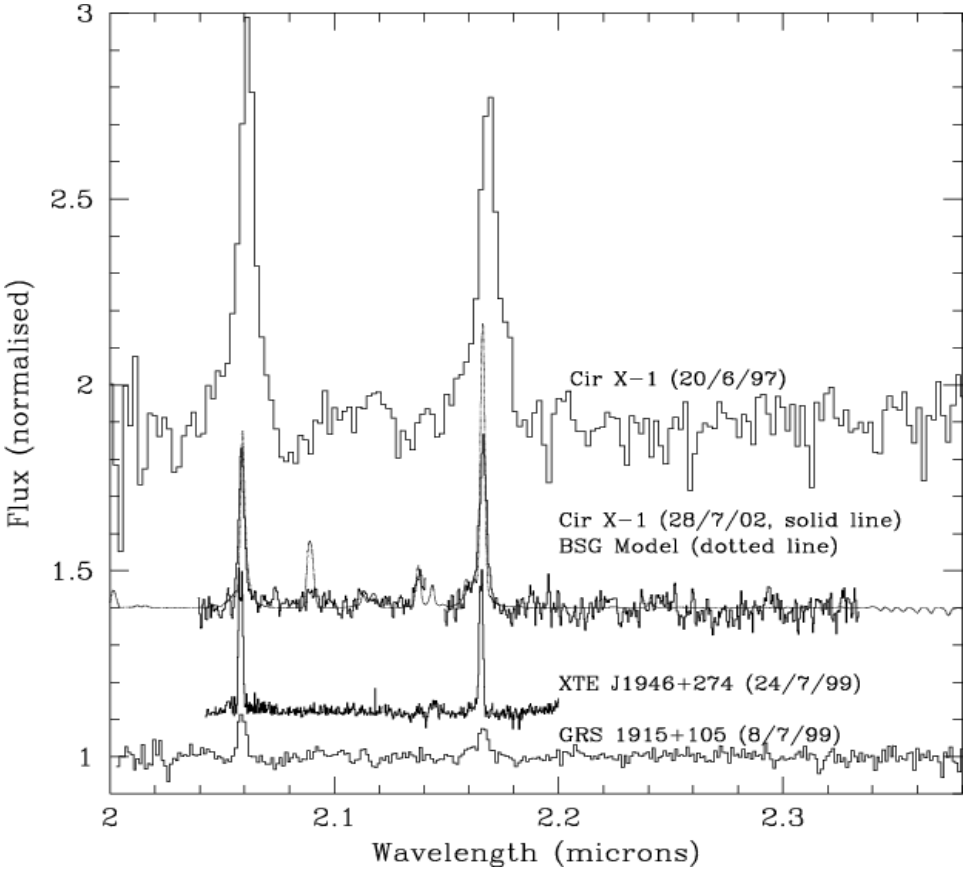
5) X-Ray Binaries - Close Binary Systems



White Dwarf, Neutron Star, or Black Hole accreting material from a Companion Star

Circinus X-1

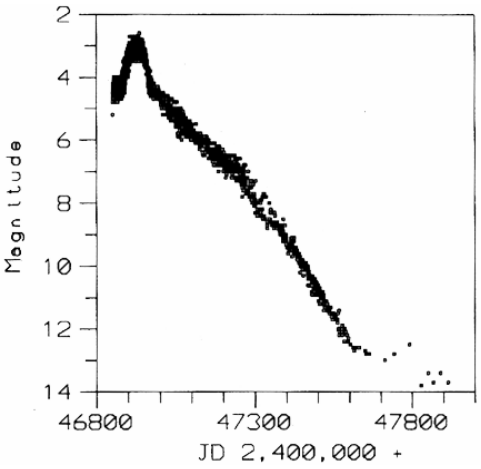




6) Supernovae

a) Type II - Core Collapse of a Massive Star

G292.0+1.8



Supernovas: When Stars Die (10-30-2006)
When a star explodes, it leaves behind a debris field of stellar material and high-energy particles known as a supernova remnant. Astronomers use Chandra to study these remnants that can produce intense X-ray radiation for thousands of years. Supernova remnants are responsible for seeding cloud that formed our Sun, planets, and ultimately us with elements like nitrogen and oxygen.

- View Video Podcast (22.2 MB, Runtime: 4:39)
- Listen to Audio Only
- Transcript

XML PODCAST

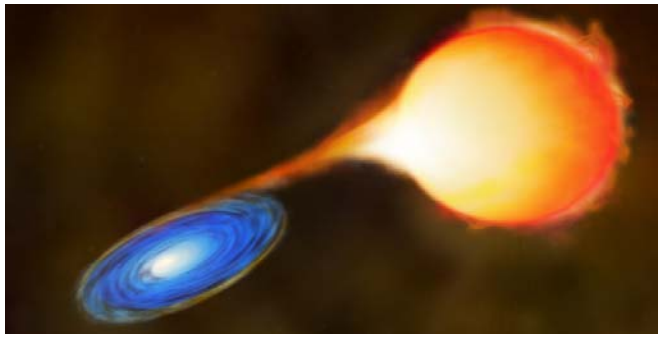
Until Their Dying Day: Stars on the Brink (09-26-2006)
Supernovas are the remnants of catastrophic explosions, and they are among the favorite targets of scientists who use Chandra, for good reason too. Supernovas and their remnants have proven to be extremely important in understanding topics ranging from the birth of our Solar System to the history and composition of the Universe itself.

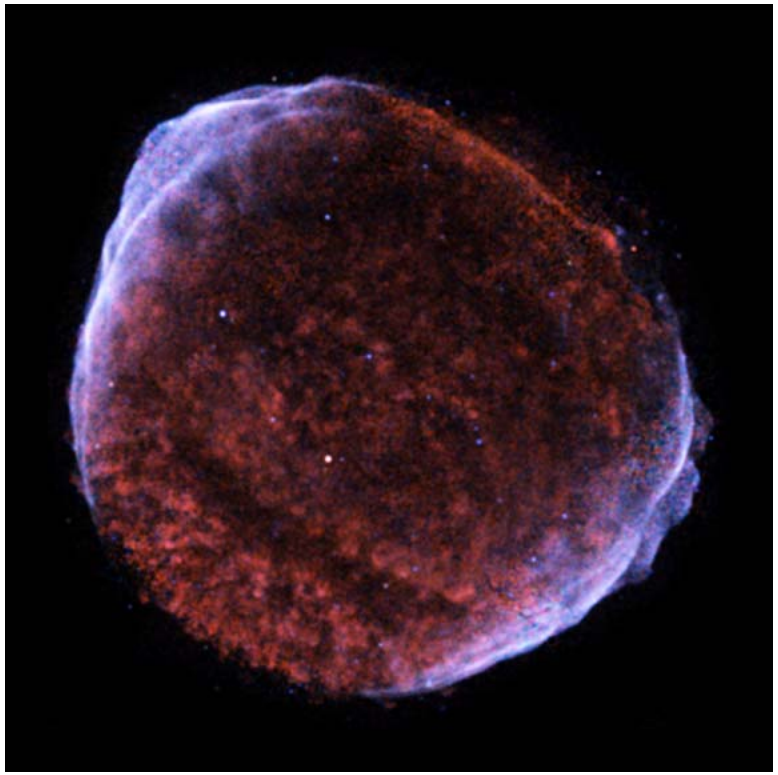
- View Video Podcast (18.1 MB, Runtime: 4:40)
- Listen to Audio Only
- Transcript

XML PODCAST

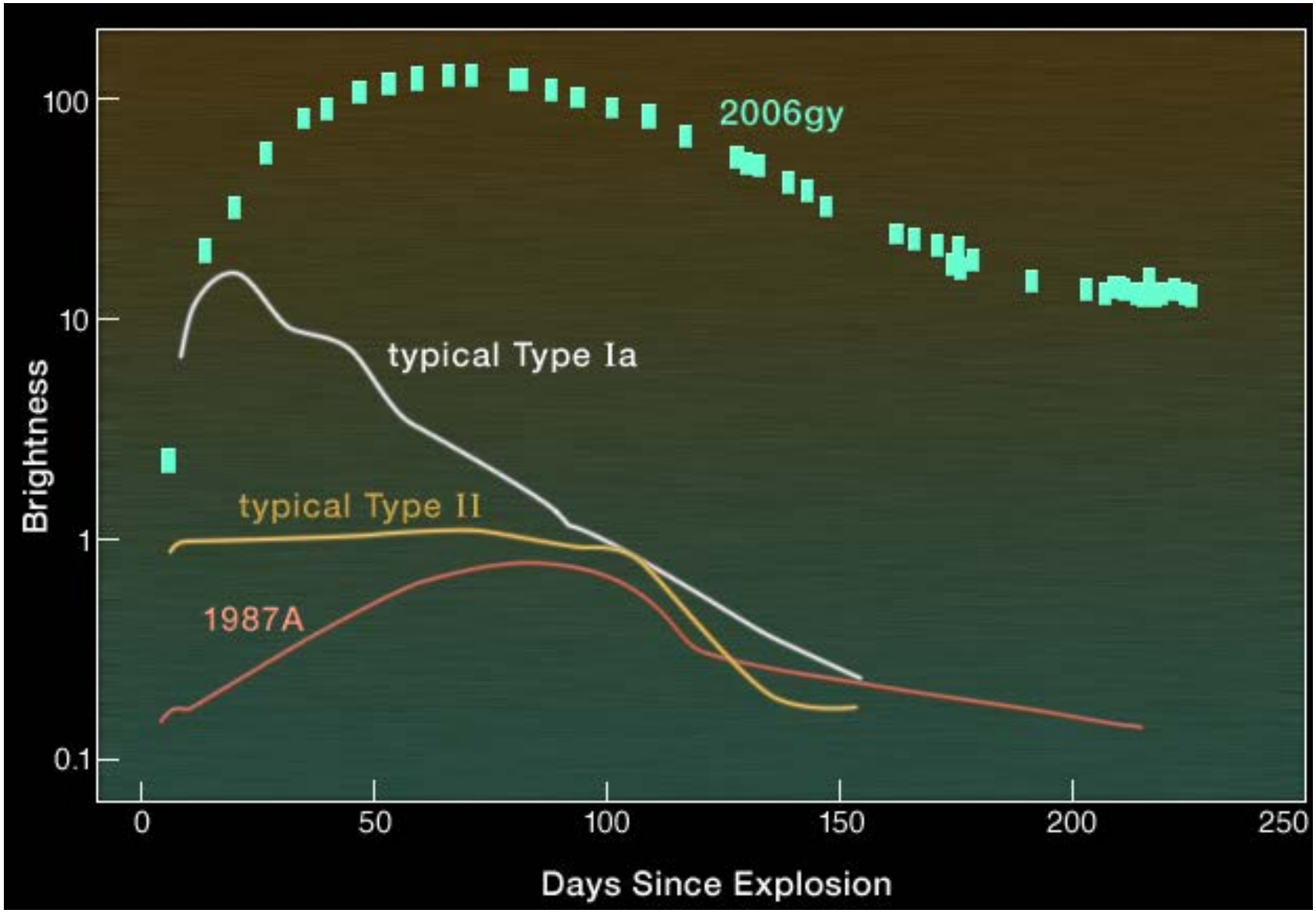
b) Type Ia - Thermonuclear Destruction of a White Dwarf in a Binary System

SN 1006



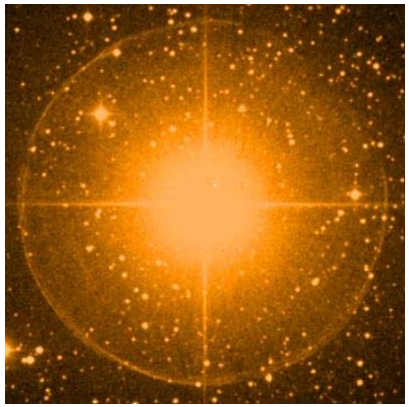


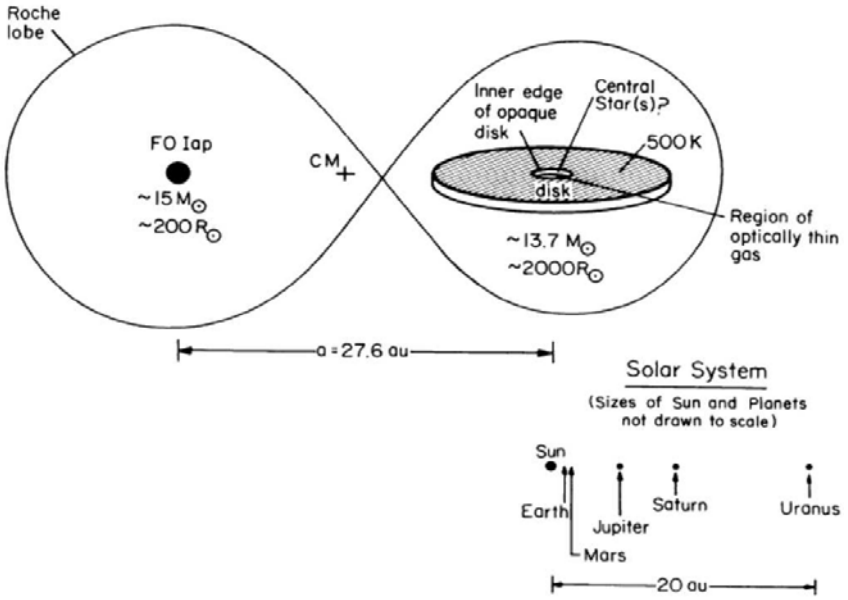
Supernovae Light Curves

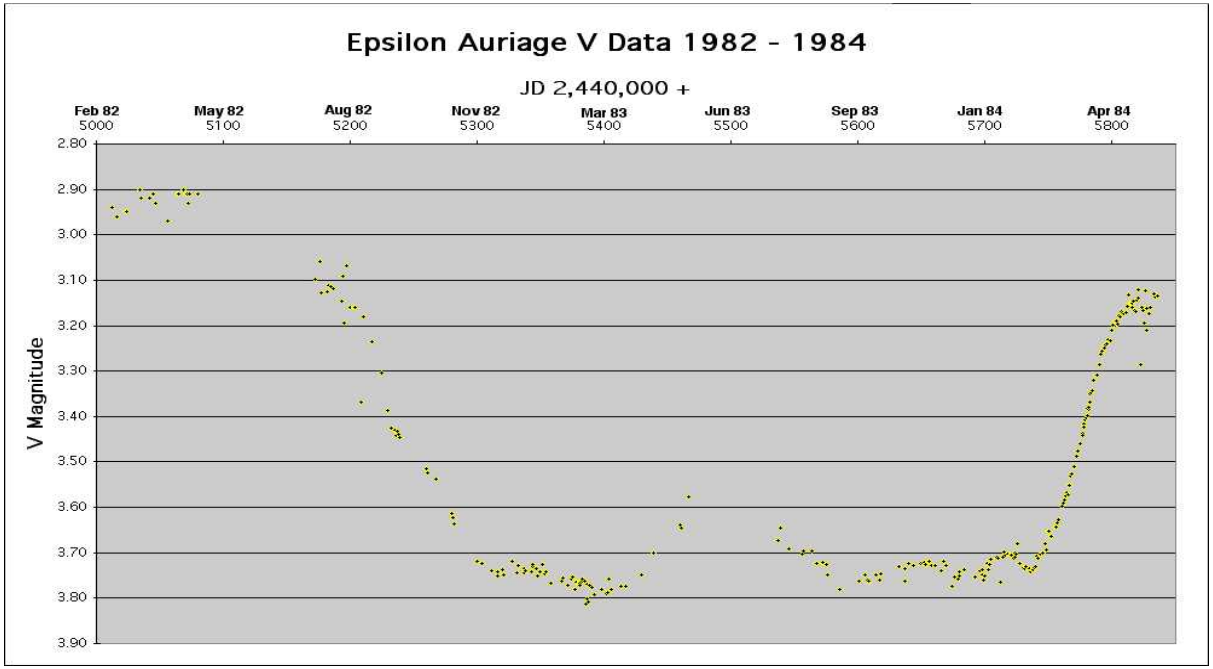


C. Eclipsing Binaries

Epsilon Aurigae



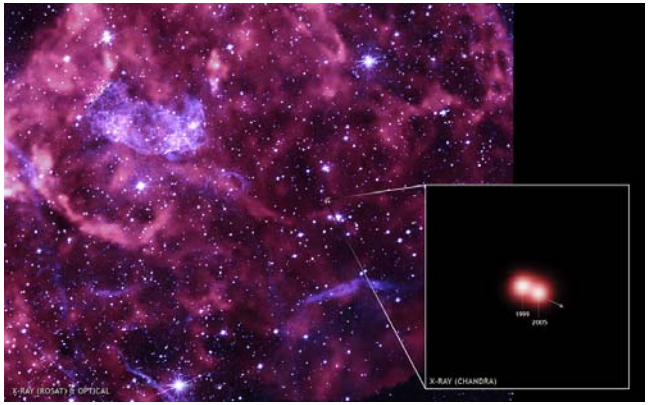




http://www.aavso.org/news/press_epsaur.shtml

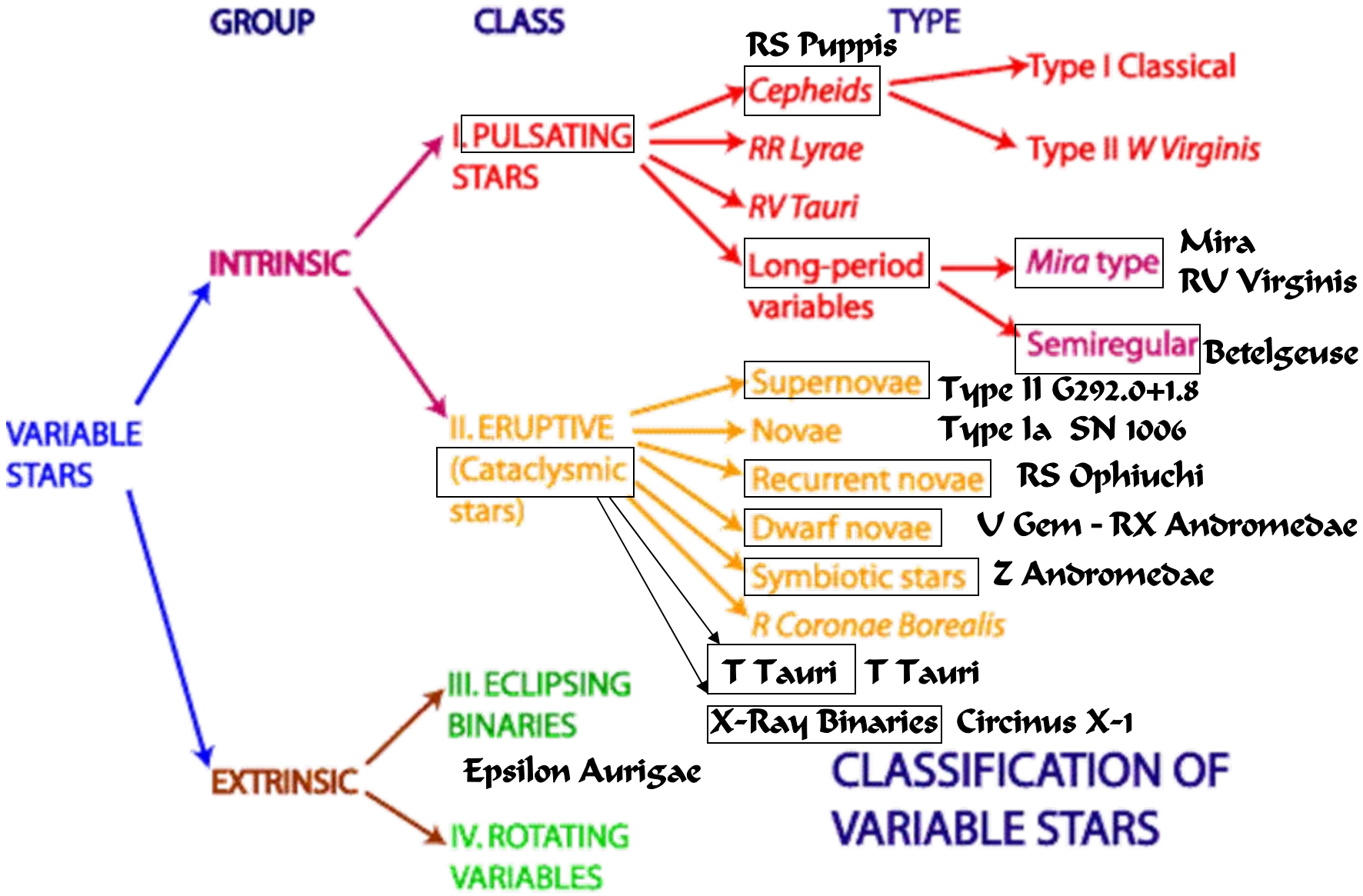
Other Deep Sky Objects:

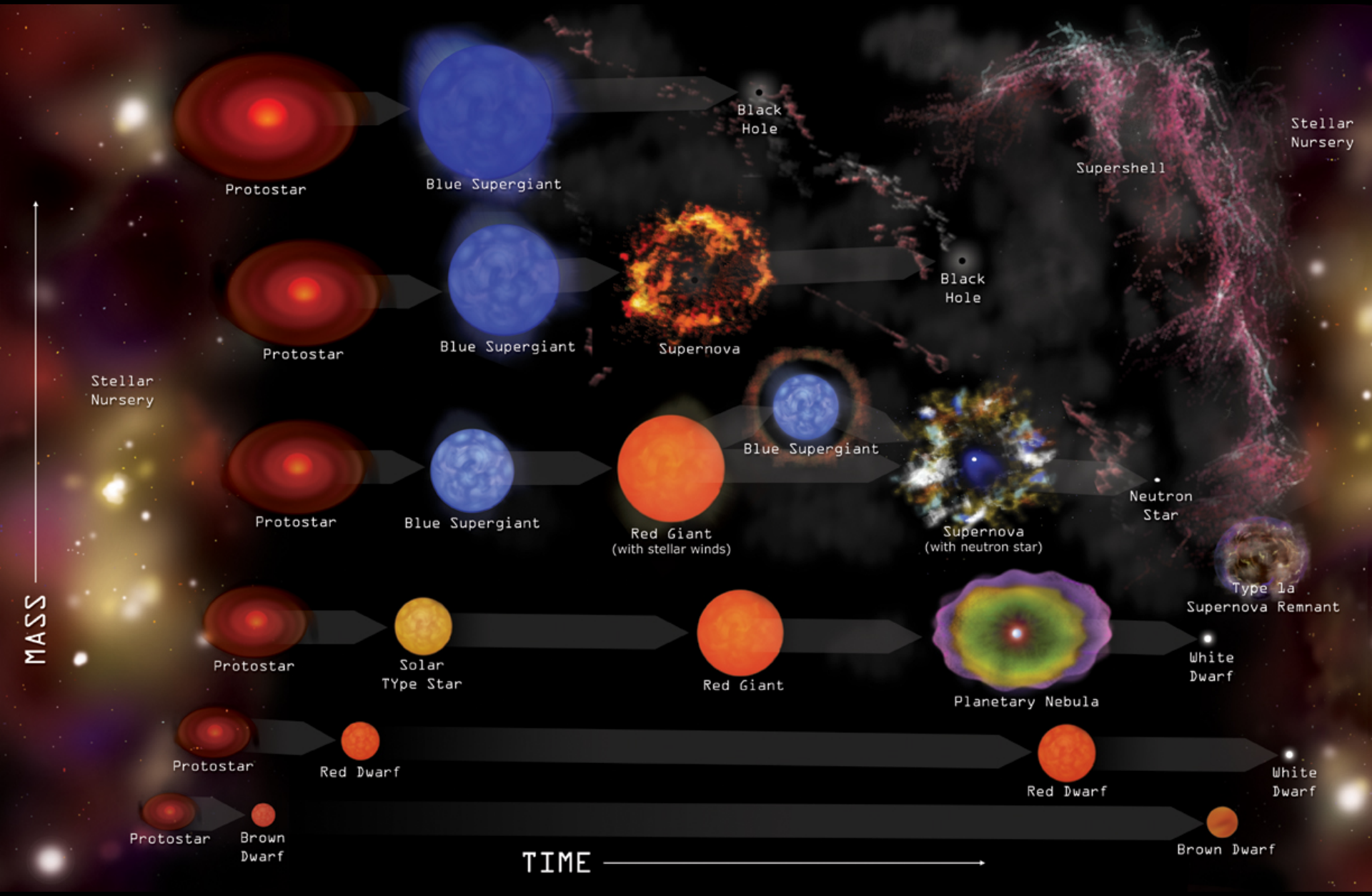
RX J0822-4300
Neutron star in Puppis A SNR

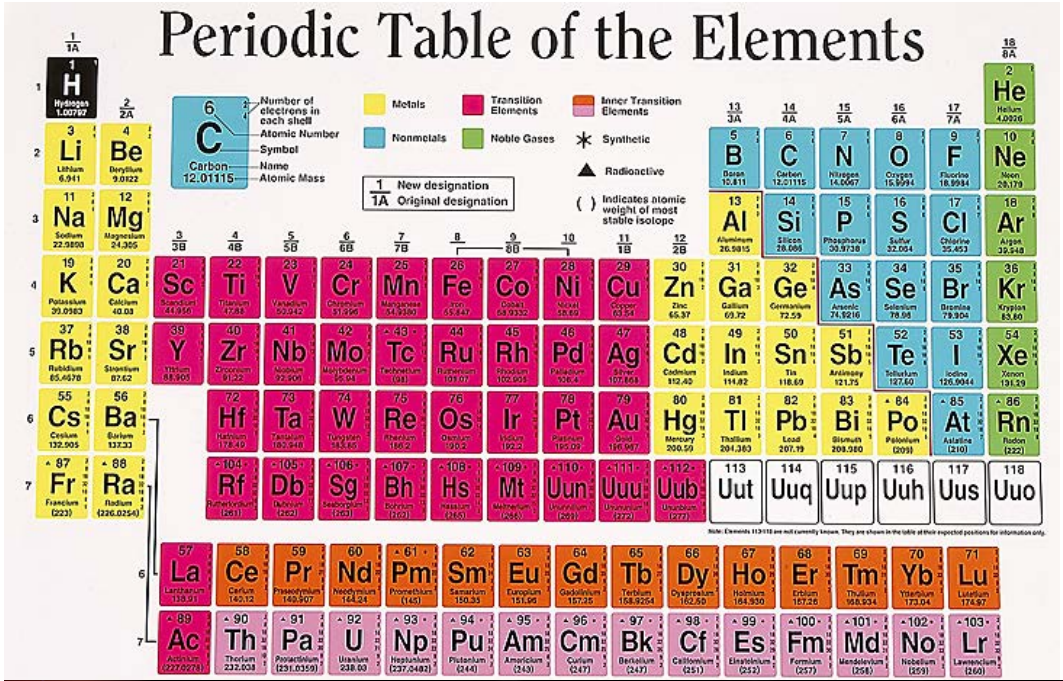


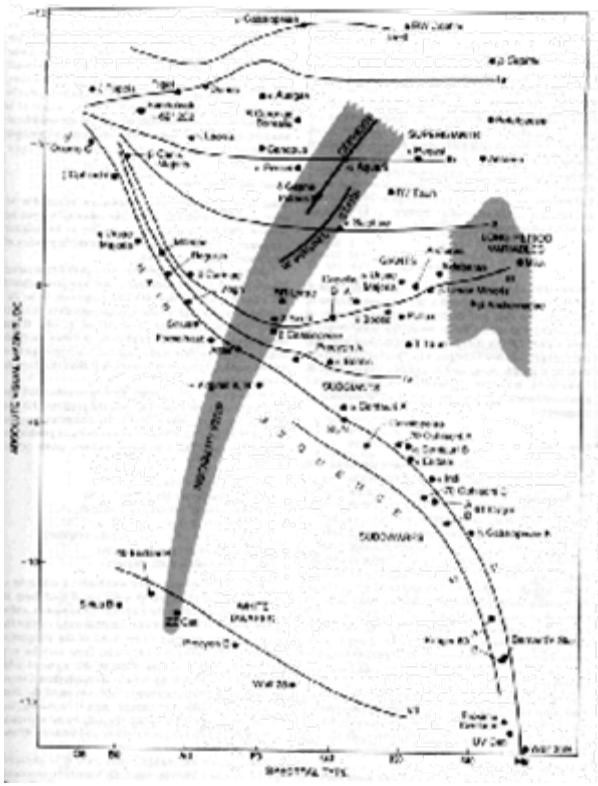
NGC 2440
Planetary Nebula

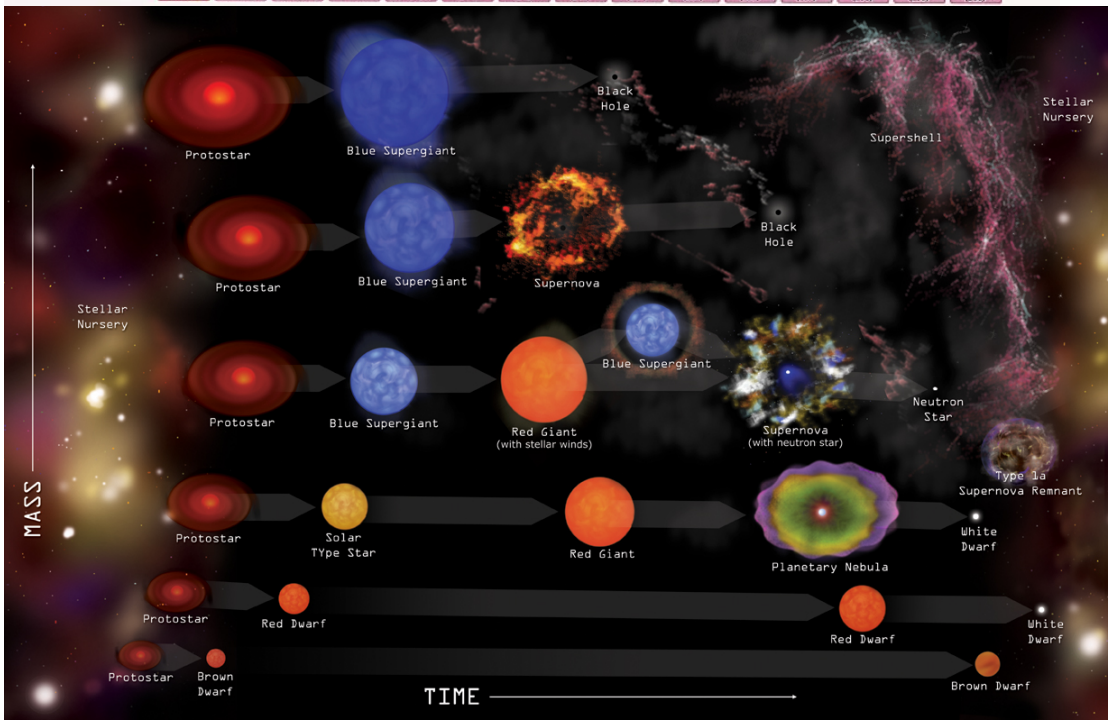
Hinds Variable Nebula
gas and dust surrounding T Tauri

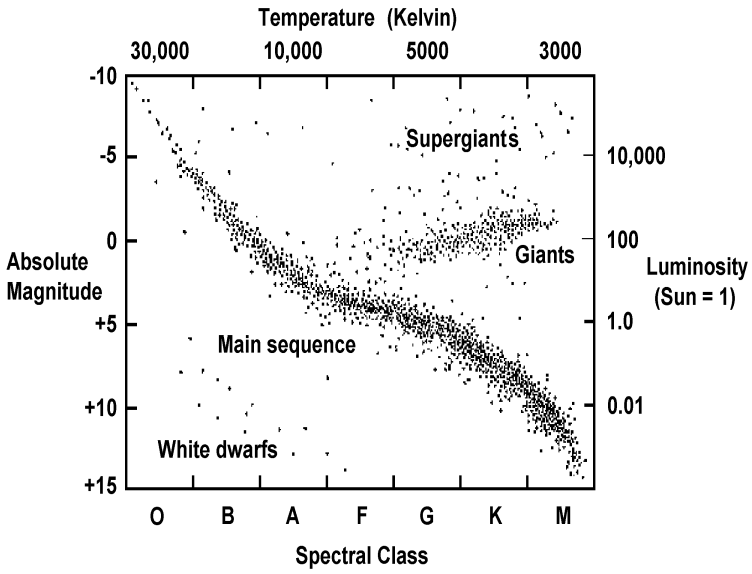

GROUP
CLASS
TYPE
VARIABLE STARS
INTRINSIC
EXTRINSIC
I. PULSATING STARS
II. ERUPTIVE (Cataclysmic stars)
III. ECLIPSING BINARIES
IV. ROTATING VARIABLES
RS Puppis
Cepheids
Type I Classical
Type II W Virginis
RR Lyrae
RV Tauri
Long-period variables
Mira type
Mira
RV Virginis
Semiregular
Betelgeuse
Supernovae
Type II G292.0+1.8
Novae
Type Ia SN 1006
Recurrent novae
RS Ophiuchi
Dwarf novae
U Gem - RX Andromedae
Symbiotic stars
Z Andromedae
R Coronae Borealis
T Tauri
T Tauri
X-Ray Binaries
Circinus X-1
Epsilon Aurigae
CLASSIFICATION OF VARIABLE STARS

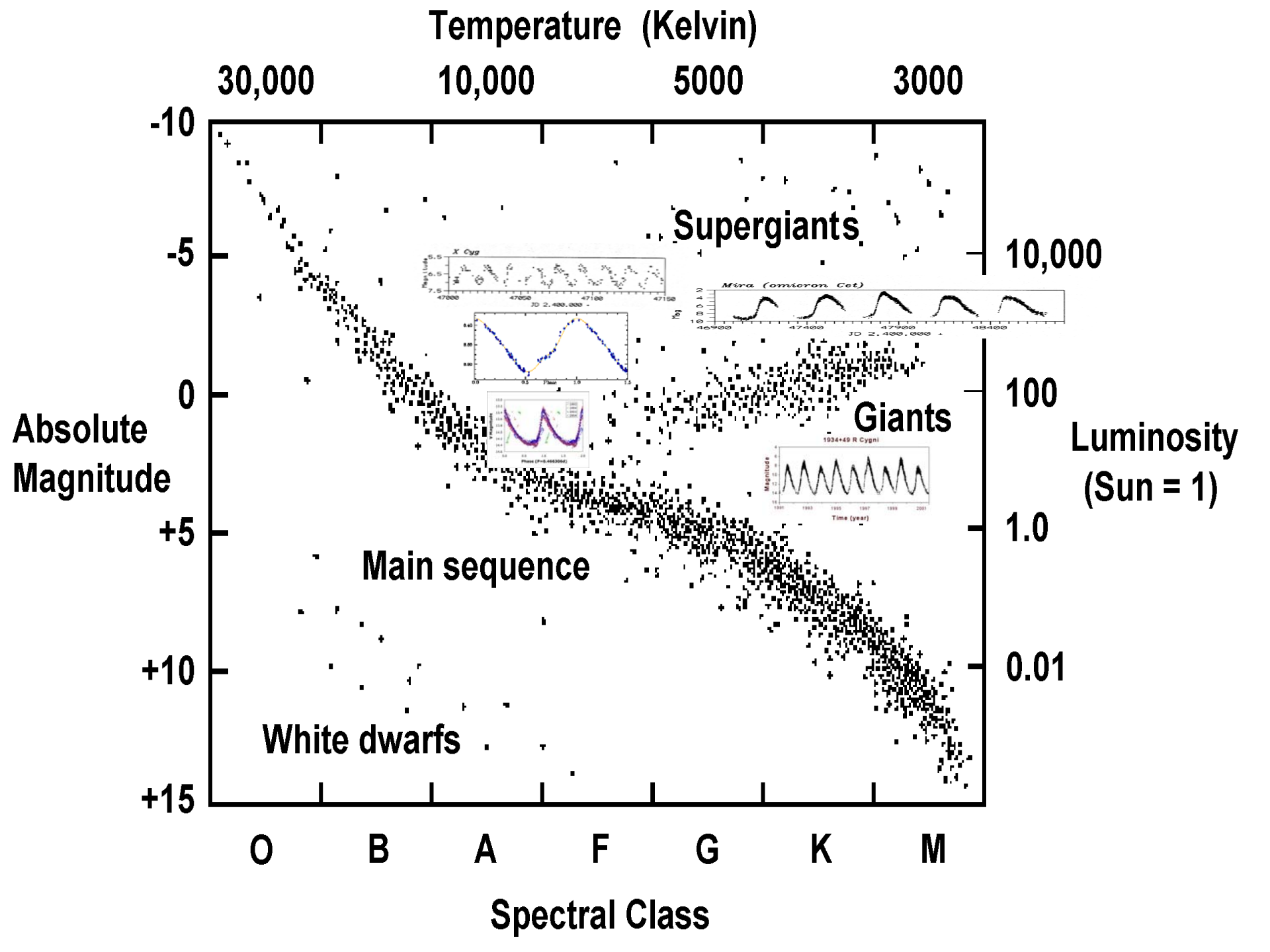

Protostar
Blue Supergiant
Black Hole
Stellar Nursery
Supershell
Stellar Nursery
Protostar
Blue Supergiant
Supernova
Black Hole
Stellar Nursery
Protostar
Blue Supergiant
Red Giant
(with stellar winds)
Blue Supergiant
Supernova
(with neutron star)
Neutron Star
Type 1a
Supernova Remnant
Protostar
Solar
TYpe Star
Red Giant
Planetary Nebula
White Dwarf
Protostar
Red Dwarf
Red Dwarf
White Dwarf
Protostar
Brown Dwarf
Brown Dwarf
MASS
TIME


Periodic Table of the Elements
Number of electrons in each shell
Atomic Number
Symbol
Name
Atomic Mass
Carbon
12.01115
Metals
Nonmetals
Transition Elements
Noble Gases
Inner Transition Elements
Synthetic
Radioactive
1 New designation
1A Original designation
( ) Indicates atomic weight of most stable isotope
H Hydrogen 1.00797
He Helium 4.0026
Li Lithium 6.941
Be Beryllium 9.0122
B Boron 10.811
C Carbon 12.01115
N Nitrogen 14.0067
O Oxygen 15.9994
F Fluorine 18.9984
Ne Neon 20.179
Na Sodium 22.9898
Mg Magnesium 24.305
Al Aluminum 26.9815
Si Silicon 28.086
P Phosphorus 30.9738
S Sulfur 32.064
Cl Chlorine 35.453
Ar Argon 39.948
K Potassium 39.0983
Ca Calcium 40.08
Sc Scandium 44.9559
Ti Titanium 47.88
V Vanadium 50.9415
Cr Chromium 51.996
Mn Manganese 54.9380
Fe Iron 55.847
Co Cobalt 58.9332
Ni Nickel 58.69
Cu Copper 63.54
Zn Zinc 65.37
Ga Gallium 69.72
Ge Germanium 72.59
As Arsenic 74.9216
Se Selenium 78.96
Br Bromine 79.904
Kr Krypton 83.80
Rb Rubidium 85.4678
Sr Strontium 87.62
Y Yttrium 88.905
Zr Zirconium 91.22
Nb Niobium 92.906
Mo Molybdenum 95.94
Tc Technetium (98)
Ru Ruthenium 101.07
Rh Rhodium 102.905
Pd Palladium 106.4
Ag Silver 107.868
Cd Cadmium 112.40
In Indium 114.82
Sn Tin 118.69
Sb Antimony 121.75
Te Tellurium 127.60
I Iodine 126.9044
Xe Xenon 131.29
Cs Cesium 132.905
Ba Barium 137.33
Hf Hafnium 178.49
Ta Tantalum 180.948
W Tungsten 183.85
Re Rhenium 186.2
Os Osmium 190.2
Ir Iridium 192.2
Pt Platinum 195.09
Au Gold 196.967
Hg Mercury 200.59
Tl Thallium 204.383
Pb Lead 207.19
Bi Bismuth 208.980
Po Polonium (209)
At Astatine (210)
Rn Radon (222)
Fr Francium (223)
Ra Radium (226.0254)
Rf Rutherfordium (261)
Db Dubnium (262)
Sg Seaborgium (263)
Bh Bohrium (262)
Hs Hassium (265)
Mt Meitnerium (266)
Uun Ununnilium (269)
Uuu Unununium (272)
Uub Ununbium (277)
Uut Uuq Uup Uuh Uus Uuo
La Lanthanum 138.91
Ce Cerium 140.12
Pr Praseodymium 140.907
Nd Neodymium 144.24
Pm Promethium (145)
Sm Samarium 150.35
Eu Europium 151.96
Gd Gadolinium 157.25
Tb Terbium 158.9254
Dy Dysprosium 162.50
Ho Holmium 164.930
Er Erbium 167.26
Tm Thulium 168.934
Yb Ytterbium 173.04
Lu Lutetium 174.97
Ac Actinium (227.0278)
Th Thorium 232.038
Pa Protactinium (231.0359)
U Uranium 238.00
Np Neptunium (237.0482)
Pu Plutonium (244)
Am Americium (243)
Cm Curium (247)
Bk Berkelium (247)
Cf Californium (251)
Es Einsteinium (252)
Fm Fermium (257)
Md Mendelevium (258)
No Nobelium (259)
Lr Lawrencium (260)
Note: Elements 113-118 are not currently known. They are shown in the table at their expected positions for information only.

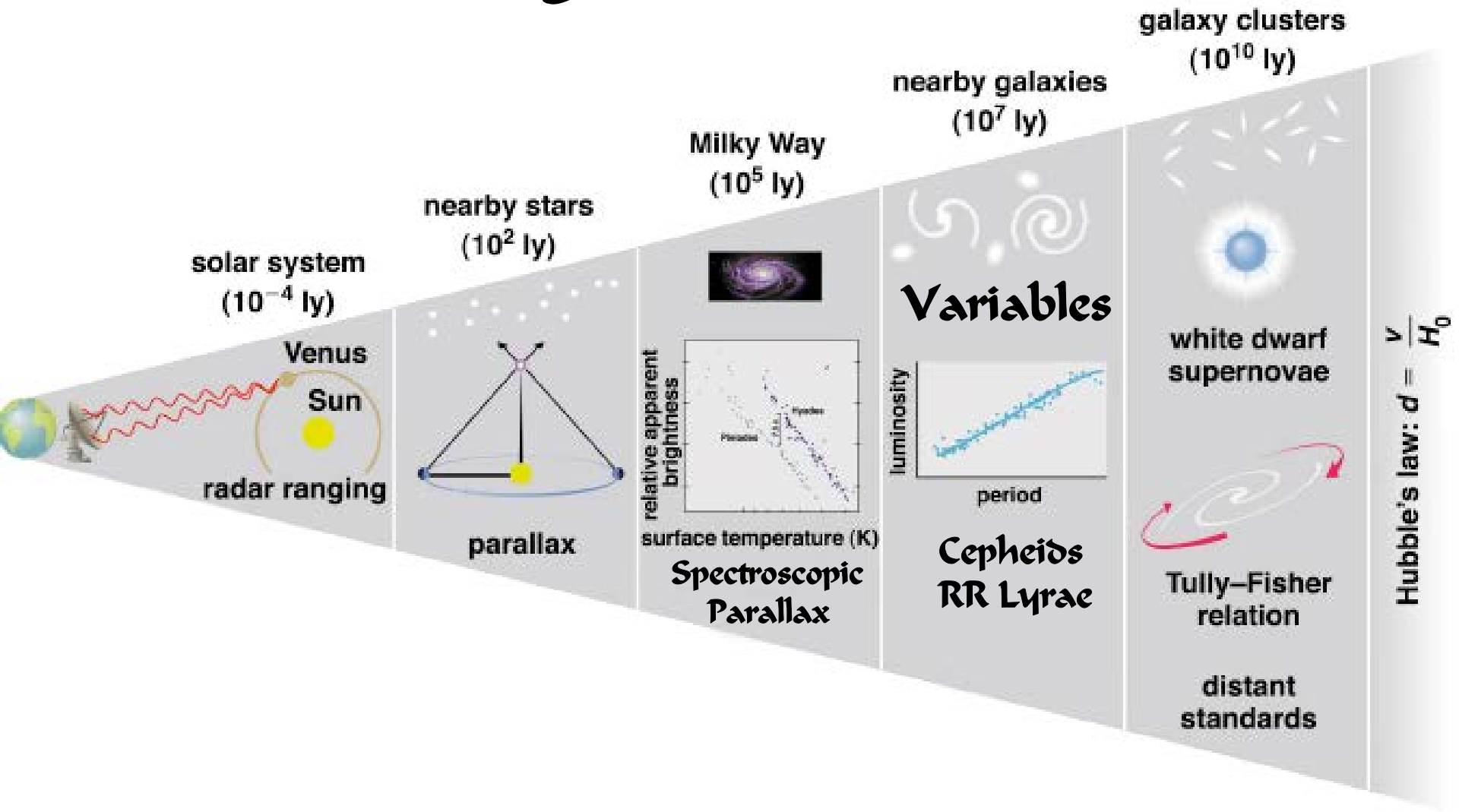



Protostar
Blue Supergiant
Black Hole
Supershell
Stellar Nursery
Protostar
Blue Supergiant
Supernova
Black Hole
Stellar Nursery
Blue Supergiant
Protostar
Blue Supergiant
Red Giant
(with stellar winds)
Supernova
(with neutron star)
Neutron Star
Type 1a
Supernova Remnant
Protostar
Solar
TYpe Star
Red Giant
Planetary Nebula
White Dwarf
Protostar
Red Dwarf
Red Dwarf
White Dwarf
Protostar
Brown Dwarf
Brown Dwarf
MASS
TIME


Temperature (Kelvin)
30,000
10,000
5000
3000
-10
-5
0
+5
+10
+15
Absolute Magnitude
Supergiants
Giants
Main sequence
White dwarfs
10,000
100
1.0
0.01
Luminosity (Sun = 1)
O
B
A
F
G
K
M
Spectral Class

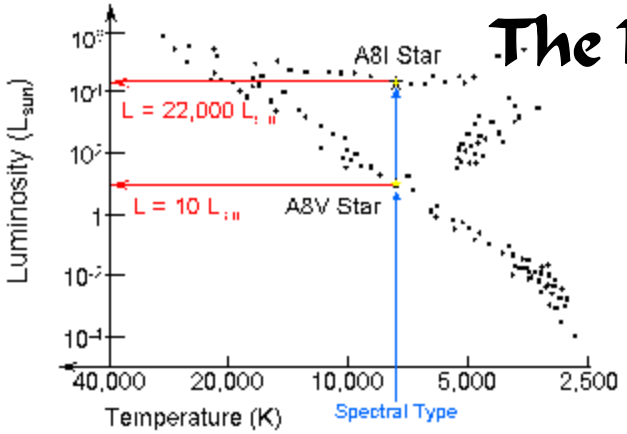

Temperature (Kelvin)
30,000
10,000
5000
3000
-10
-5
0
+5
+10
+15
Absolute Magnitude
10,000
100
1.0
0.01
Luminosity (Sun = 1)
Supergiants
Giants
Main sequence
White dwarfs
X Cyg
Mira (omicron Cet)
1934+49 R Cygni
O
B
A
F
G
K
M
Spectral Class

Cosmological Distances



Cosmological Distances

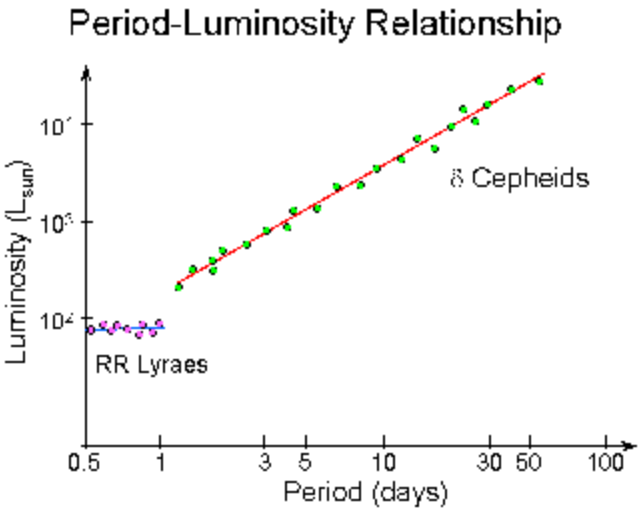
➔Spectroscopic Parallax

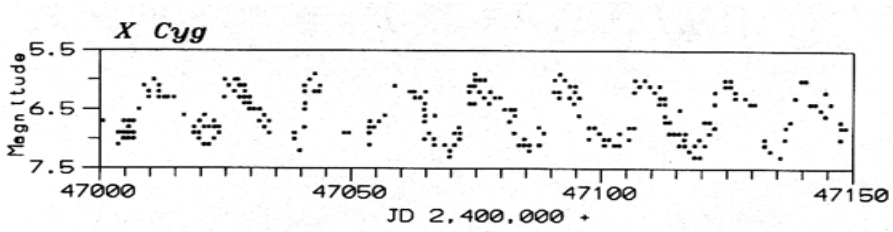


The Distance Modulus: $M = m - 5\log_{10}\frac{(r)}{10}$

➔Cepheids

The Distance Modulus: $M = m - 5\log_{10}\frac{(r)}{10}$





Cosmological Distances & Candles

➔ Type Ia Supernovae - Standard Candle

$M_v = -19.5$

The Distance Modulus: $M = m - 5\log_{10}\left(\frac{r}{10}\right)$

Basic Equations and Relationships

The Distance Modulus: $M = m - 5\log_{10}\left(\frac{r}{10}\right)$

Kepler's 3rd Law: $(M_A + M_B) = \frac{a^3}{p^2}$

$v = \frac{d}{t}$; $a = \frac{v}{t}$; $2\pi a = vP$; $F_c = ma_c$; $a_c = \frac{v^2}{r} = r\omega^2$

1 pc = 206,265 au = 3.26 ly = 3.08×10^{16}m

1° = 60 arcmin = 60′ ; 1′ = 60 arcsec = 60″

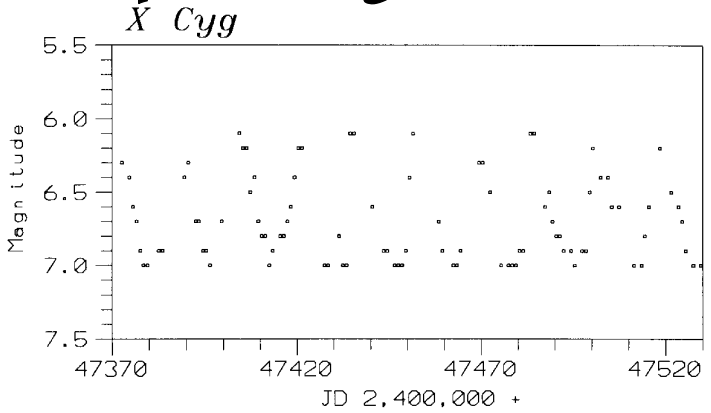
Inverse Square Law: $L = 1/r^2$

Circumference, Area, Surface Area, and Volume of a Sphere

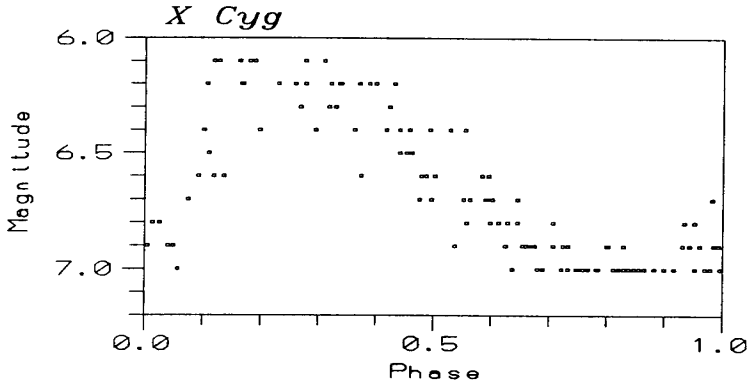
REARRANGE ALL EQUATIONS FOR EACH VARIABLE

Phase Diagrams

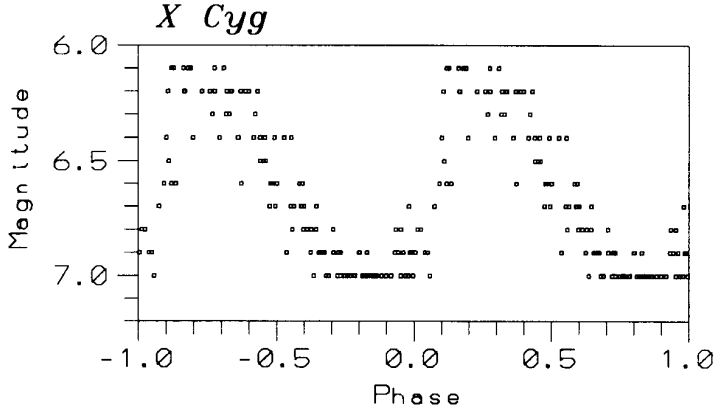
1) Cepheid Light Curve



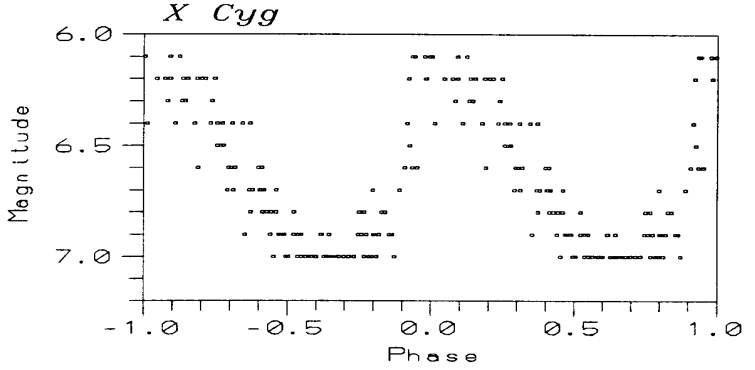
2) Superposition of Periods



3) Same Data Plotted Twice

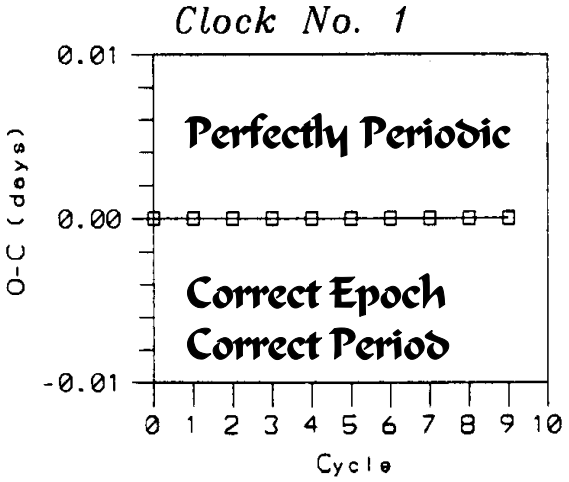


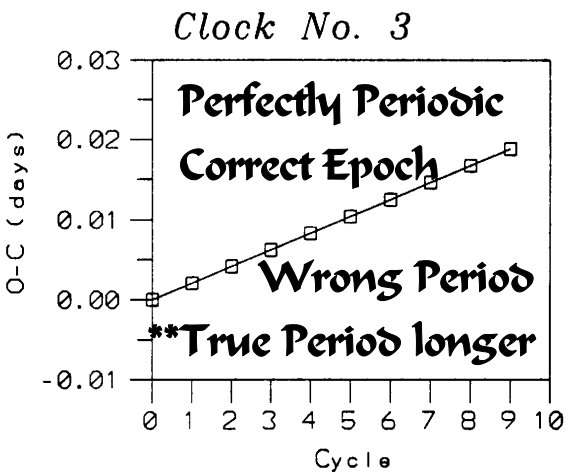
4) Same data starting at Maxima

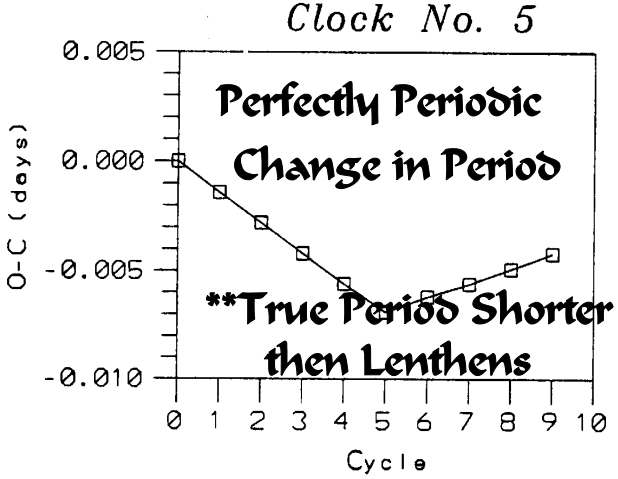


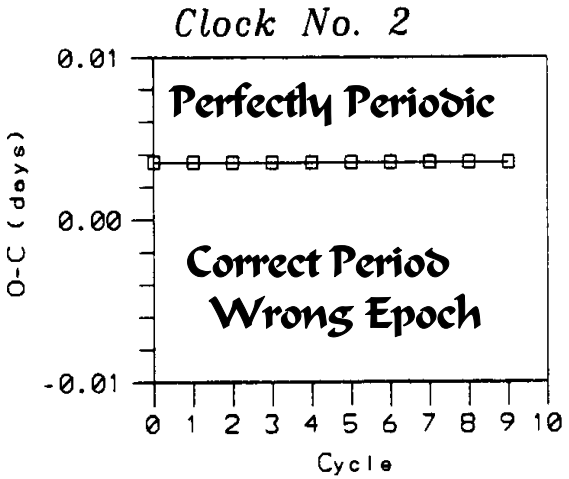
O - C Diagrams
(Observed minus Calculated)

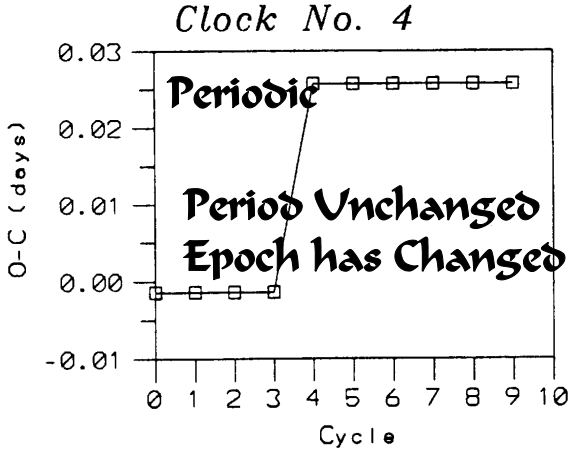
Theory Matches Observation

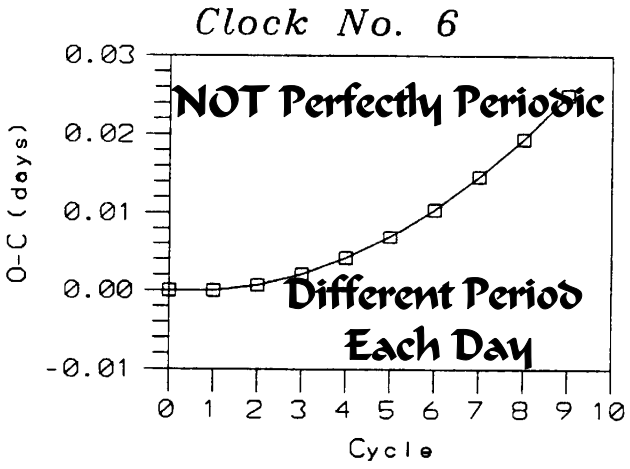












** The slope of each line is the difference between its period and the estimated period.

Variable Stars

Stars appear to shine with a constant light; however, thousands of stars vary in brightness. The brightness that a star appears to have (apparent magnitude) from our perspective here on Earth depends upon its distance from Earth and its actual intrinsic brightness (absolute magnitude.) The behavior of stars that vary in magnitude (brightness) - known as variable stars - can be studied by measuring their changes in brightness over time and plotting the changes on a graph called a light curve. Amateur astronomers around the world observe variable stars and assist professional astronomers by sending their data to variable star organizations, such as the American Association of Variable Star Observers (AAVSO) in Cambridge, Massachusetts. The behavior of some variable stars can be observed with the unaided eye or binoculars. Measuring and recording the changes in apparent magnitude and drawing the resulting light curves will allow you to begin to unravel the stories of the often turbulent and always exciting lives of variable stars. The collection and study of variable star data requires the ability to estimate the apparent magnitudes of stars. The two activities that follow will assist you in acquiring the skill of estimating the magnitudes of variable stars.

The two activities, Stellar Heartbeats and A Variable Star in Cygnus, have been adapted from the "Hands-On-Astrophysics, Variable Stars in Math, Science, and Computer Education" curriculum project developed and published by the American Association of Variable Star Observers (AAVSO.)

Activity #1: Stellar Heartbeats html | flash | pdf | ppt
Activity #2: A Variable Star in Cygnus html | flash | pdf | ppt
Alignment of Performance Task with National Stardards: html | pdf

Useful Resources:

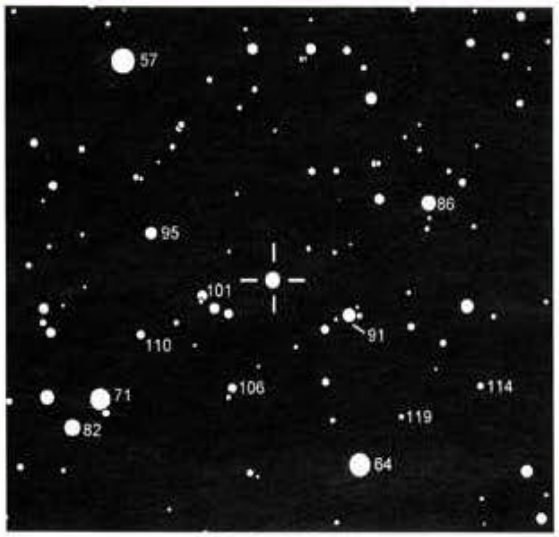
- Types of Variable Stars (at AAVSO)
- Estimating Magnitudes Using Interpolation (at AAVSO)

Chandra :: Educational Materials :: Variable Stars (Flash Version) - Netscape

File Edit View Go Bookmarks Tools Window Help

ACTIVITY #1 - STELLAR HEARTBEATS

Recording Stellar Heartbeats



JD 2449050

next image >

Estimate the magnitude of your variable star on the first picture of the star field using the magnitudes of the stars around it. Proceed through each of the pictures and place your estimated magnitude next to the corresponding JD in the table provided.

Julian Date	Magnitute
JD 2449050	
JD 2449110	
JD 2449150	
JD 2449180	
JD 2449240	
JD 2449300	
JD 2449350	
JD 2449375	
JD 2449435	
JD 2449500	
JD 2449540	
JD 2449635	
JD 2449700	
JD 2449740	
JD 2449760	
JD 2449800	
JD 2449870	
JD 2449950	

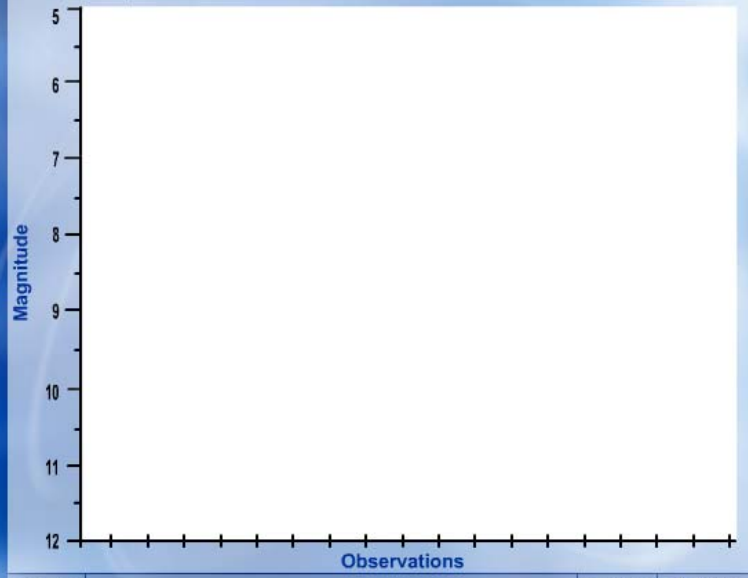
CLOSE BACK NEXT

ACTIVITY #1 - STELLAR HEARTBEATS

JD 2449050 JD 2449110 JD 2449150 JD 2449180 JD 2449240 JD 2449300 JD 2449350 JD 2449375 JD 2449435

JD 2449500 JD 2449540 JD 2449635 JD 2449700 JD 2449740 JD 2449760 JD 2449800 JD 2449870 JD 2449950

Study the resulting light curve. Does this variable star show periodic behavior? Is this the light curve for a Cepheid variable star?



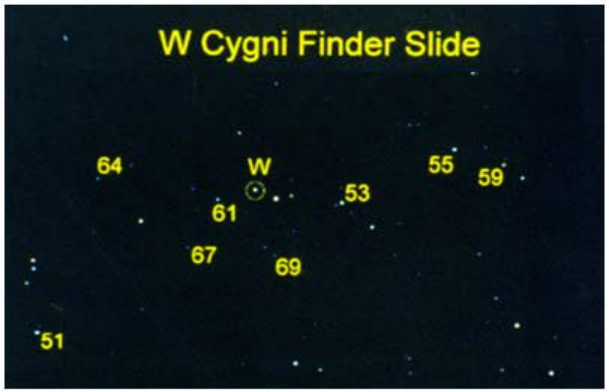
CLOSE PRINT BACK

Chandra Chronicles

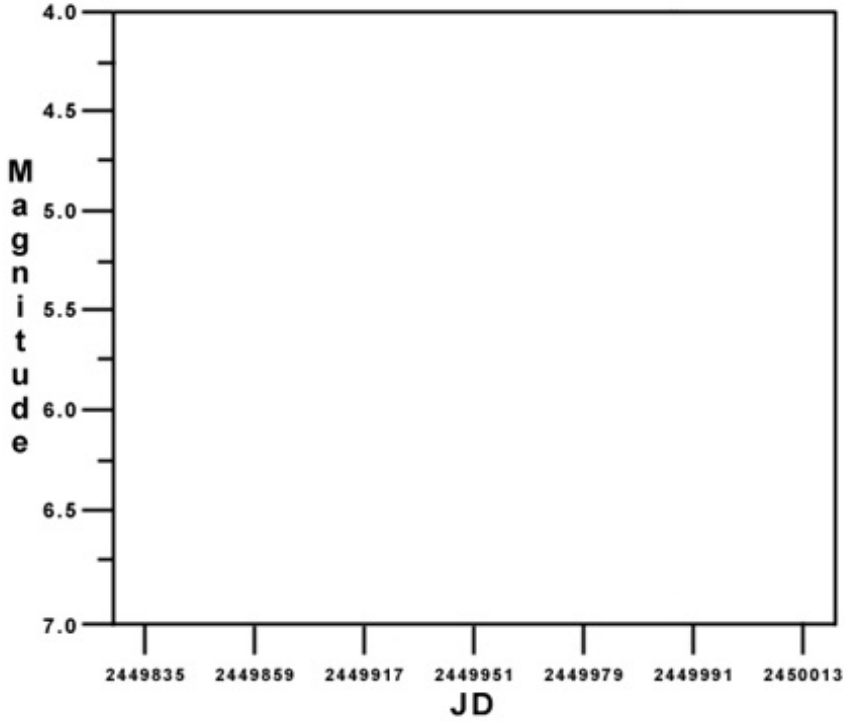
Variable Stars in Cygnus: Estimating Magnitudes

The W Cyg Field Slide #1 is the first of a series of 7 slides taken of the variable star over a period of approximately 150 days. The set covers nearly the entire range from maximum magnitude (brightest) to minimum magnitude (dimmest.) You will note as you move through the slides that W Cyg does not appear in exactly the same spot in each of the slides. This is because it is difficult for a photographer to set up in the exact same spot when photographing the sky several days apart. The slides also appear in different hues and sometimes with fewer stars in the field. This is the result of different atmospheric conditions on the dates that Cygnus and W Cyg were photographed.

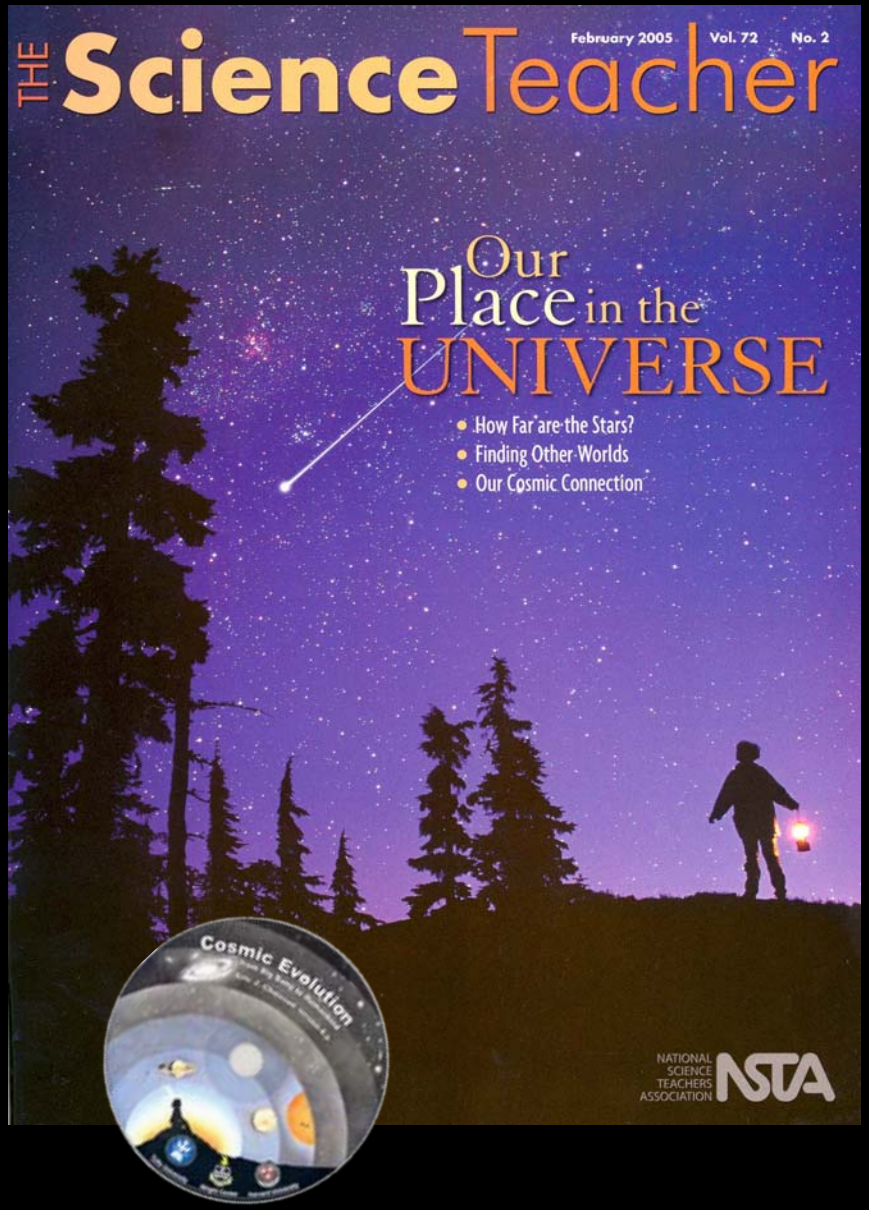
A finder slide with W Cyg and the comparison stars circled has been provided below. Use it to locate W Cyg and the magnitudes of the comparison stars in the sequence of images beneath it.

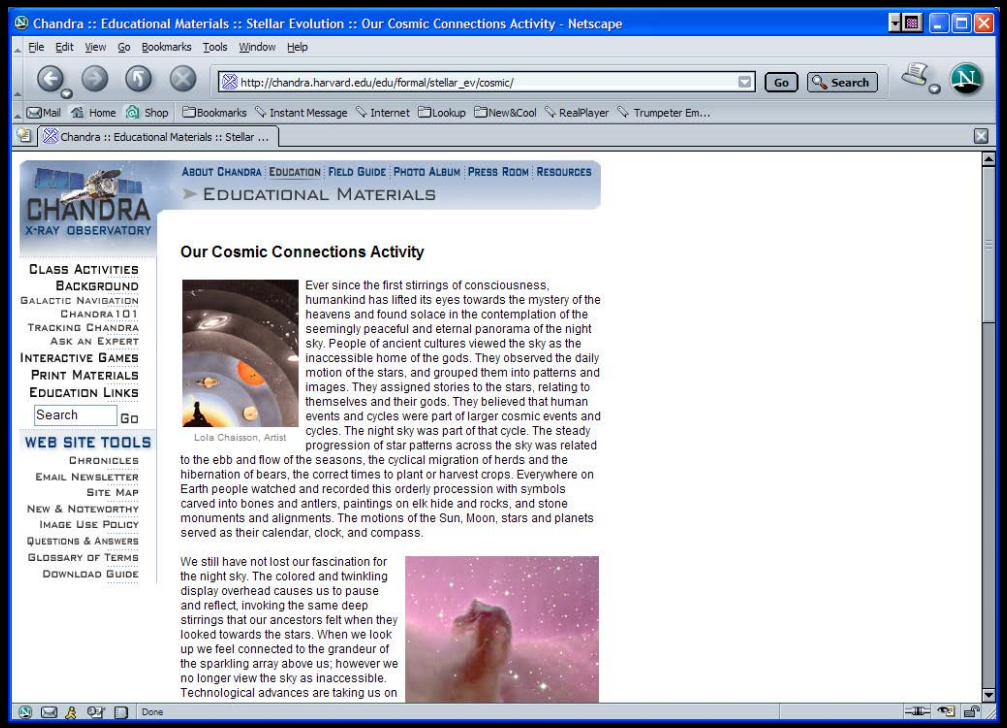


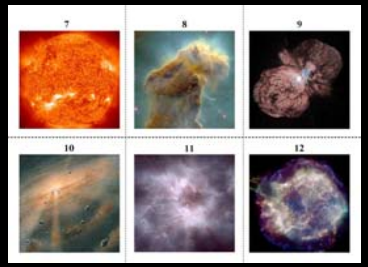
JD 2449835

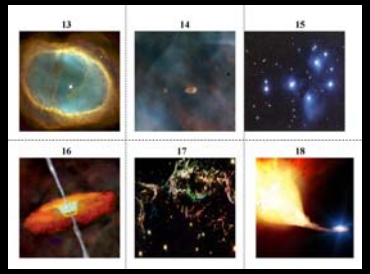


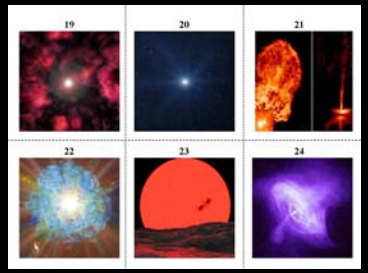
Stellar Evolution - A Journey with Chandra



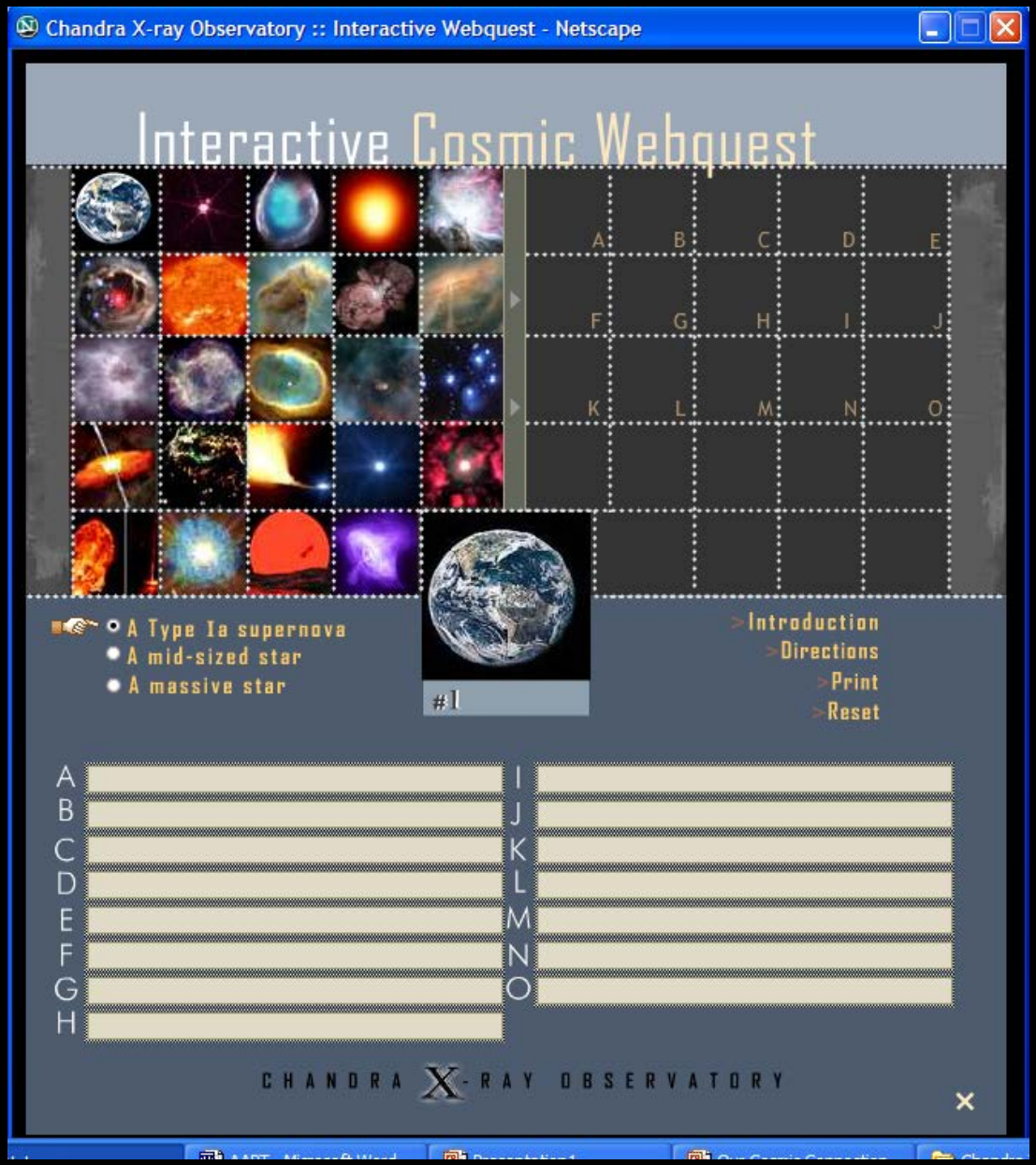


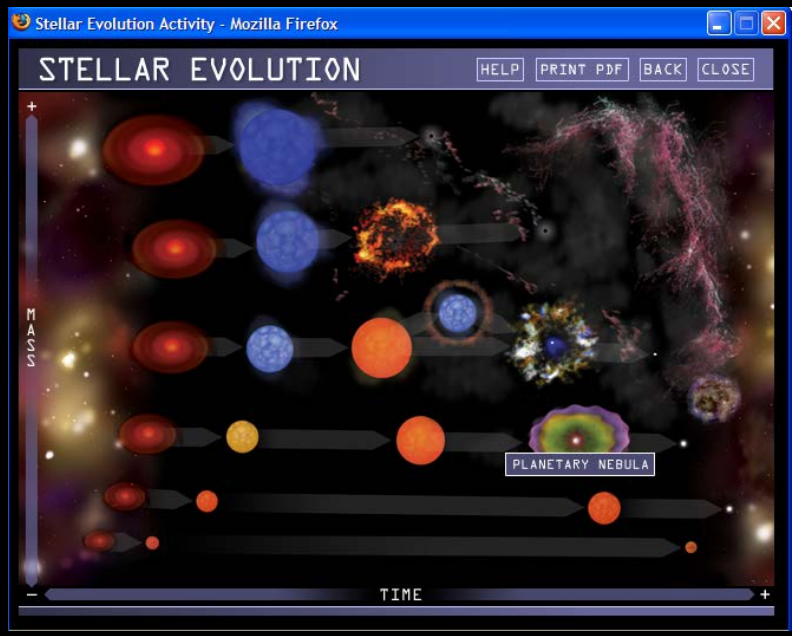


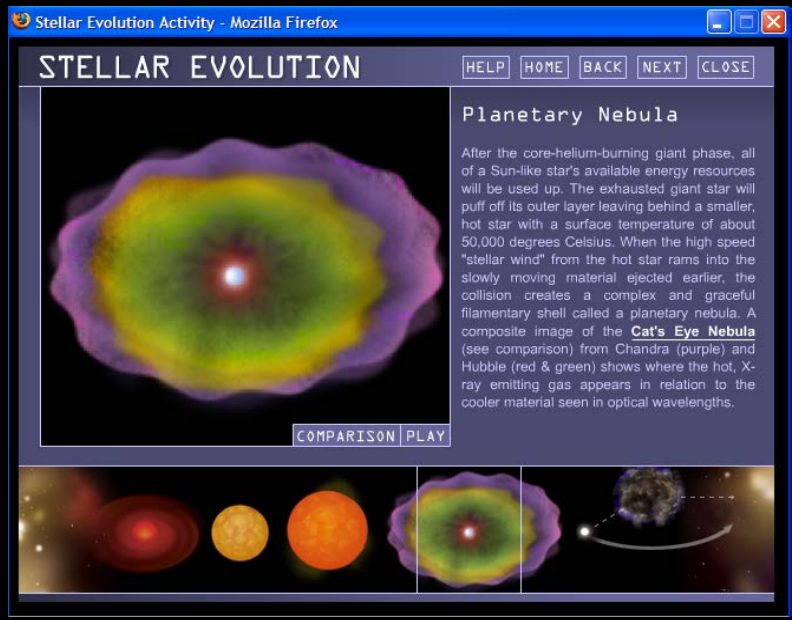




Stellar Evolution - A Journey with Chandra

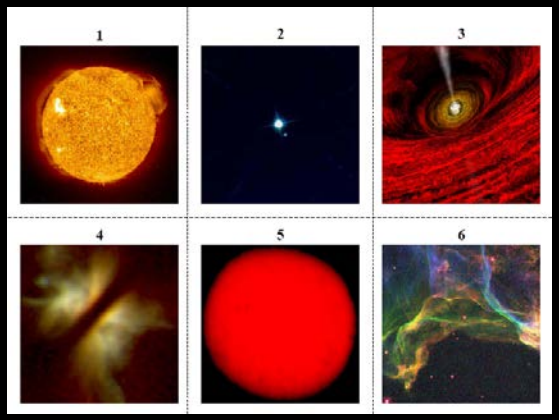


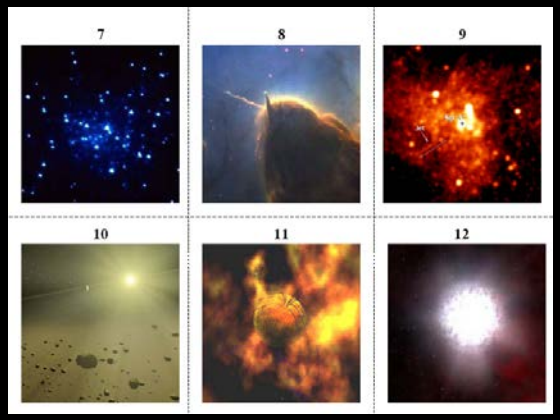


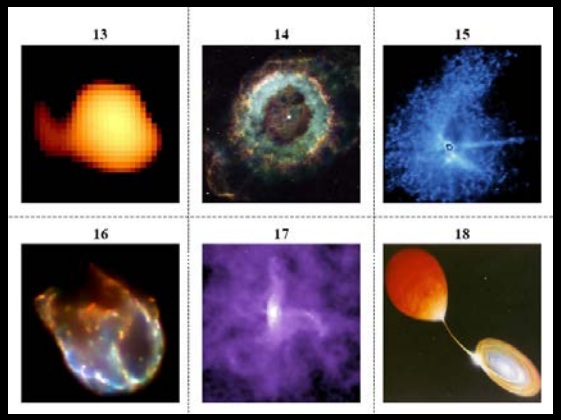


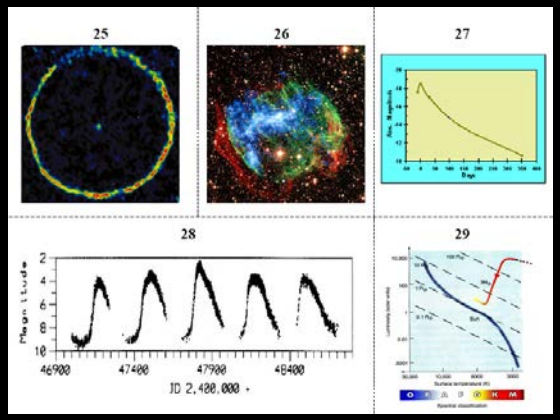
Stellar Cycles Sets and Cosmic Connections Request URL: http://chandra.harvard.edu/edu/epo/request_special.html

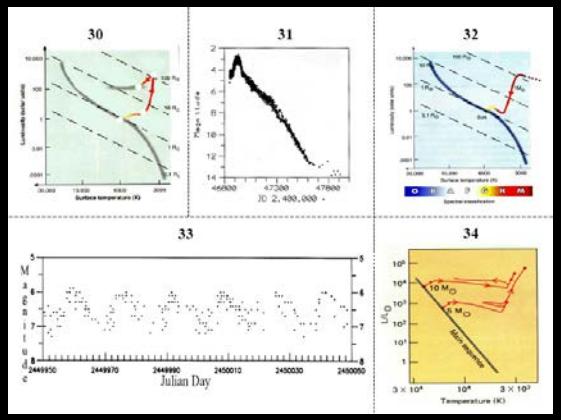
Stellar Cycles Card Set:



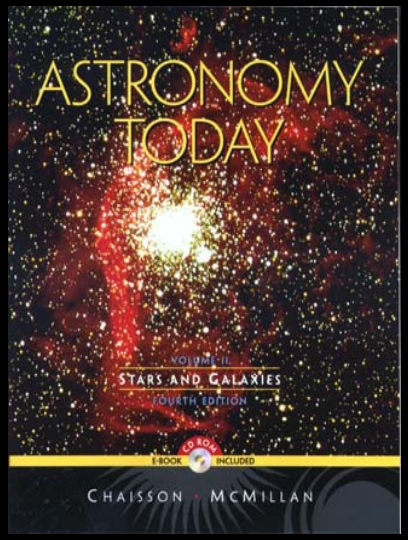








Additional Resources:



The American Association of Variable Star Observers

AAVSO: Types of Variable Stars - Mozilla Firefox

File Edit View Go Bookmarks Tools Help

http://www.aavso.org/vstar/types.shtml

AAVSO HOME > variable stars > types

Variable Stars

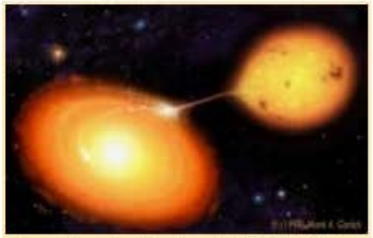
Variable Stars
Variable Star of the Season
Powerpoint Intro
Stars Easy-To-Observe
Historical Light Curves
Naming
Harvard Designation
Types
Further Reading
Research: AAVSO in Print
Observing Manual

Main sections of web
The AAVSO
Variable Stars
Observing
Access Data
Publications
Online Store
Education: HOA

Types of Variable Stars

Variable Stars are stars that vary in their light output. The origins of these light variations define the classification system of variable stars.

There are two kinds of variable stars; **intrinsic** in which variation is due to physical changes in the star or stellar system and **extrinsic** in which variability is due to the eclipse of one star by another or the effects of stellar rotation.



Impression of a Cataclysmic Variable with an Acretion Disk
Image by Mark A. Garlick
(http://space-art.co.uk)

There are four main classes of variable stars. Within the *intrinsic* group of variables there are two classes: **pulsating**and **eruptive**. Within the *extrinsic*group there are two classes: **eclipsing binary** and **rotating** stars. Below is a more thorough investigation of these four classes of variable stars.

Pulsating Variables

Pulsating Variables are stars that show periodic expansion and contraction of their surface layers. Pulsations may be radial or non-radial. A radially pulsating star remains spherical in shape, while a star experiencing non-radial pulsations

Done

http://www.soinc.org/store/TG-DVD-06v10.htm

NEWLY UPDATED COACHES MANUAL
(AVAILABLE ONLINE AT THE NSO WEBSITE)